VAN NOSTRAND'S

ECLECTIC

ENGINEERING MAGAZINE.

NO. CXII.—APRIL, 1878.—VOL. XVIII.

A NEW GENERAL METHOD IN GRAPHICAL STATICS.

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Written for VAN NOSTRAND'S MAGAZINE.

IV.

ANY FORCES LYING IN ONE PLANE, AND APPLIED AT GIVEN POINTS.

We have previously referred to this problem, having treated a particular case of it in Fig. 2; and subsequently certain statements were made respecting the indeterminateness of the process for finding the reactions of supports in case the applied forces were not vertical.

The case most frequently encountered in practice is wind-pressure combined with weight, and we can take this case as being sufficiently general in its nature; so that we are supposed to know the precise points of application of each of the forces, and its direction. Now it may be that the reaction of the supports cannot be exactly determined, but in all cases an extreme supposition can be made which will determine stresses in the framework which are on the safe side.

For example, if it is known that one of the reactions must be vertical, or normal to the bed plate of a set of supporting rollers, this will fix the direction of one reaction and the other may then be found by a process, like that employed in Fig. 2, of which the steps are as follows:

Resolve each of the forces at its point of application into components parallel and perpendicular to the known direction of the reaction, which we will call vertical for convenience, since the process is the same whatever the direction may be. By means of an equilibrium polygon or frame pencil find the line of action of the resultant of the horizontal components, whose sum is known. Then this horizontal resultant, can be treated precisely as was the single horizontal force in Fig. 2, which will determine the alteration of the vertical components of the reactions due to the couple caused by the horizontal components.

Also, find by an equilibrium polygon, or frame pencil, the vertical reactions due to the vertical components. Correct the point of division q of the weight line as found from the vertical components by the amount of alteration already found to be due to the horizontal components. Call this point q', then the polygon of the applied forces must be closed by two lines representing the reactions, which must meet on a horizontal through q'; but one of them has a known direction, hence the other is completely determined.

This determination causes the entire horizontal component to be included in a single one of the reactions, and it is usually one of the suppositions to be

made when it is not known that the reaction of a support is normal to the plane of the bed joint.

Another supposition in these circumstances is that the horizontal component is entirely included in the other reaction; and a third supposition is that the horizontal component is so divided between the reactions that they have the same direction. These suppositions will usually enable us to find the greatest possible stress on any given piece of the frame by taking that stress for each piece which is the greatest of the three.

In every supposition care must be taken to find the alteration of the vertical components due to the horizontal components. This is the point which has been usually overlooked heretofore.

KERNEL, MOMENTS OF RESISTANCE AND INERTIA: EQUILIBRIUM POLYGON METHOD.

The accepted theory respecting the flexure of elastic girders assumes that the stress induced in any cross section by a bending moment increases uniformly from the neutral axis to the extreme fiber.

The cross section considered, is supposed to be at right angles to the plane of action or solicitation of the bending moment, and the line of intersection of this plane with that of the cross section is called the axis of solicitation of the cross section.

The radius of gyration of the cross section about any neutral axis is in the direction of the axis of solicitation.

It is well known that these two axes intersect at the center of gravity of the cross section, and have directions which are conjugate to each other in the ellipse which is the locus of the extremities of the radii of gyration.

We shall assume the known relation

$$M=SI\div y$$

in which M is the magnitude of the bending moment, or moment of resistance of the cross section, S is the stress on the extreme fiber, I is the moment of inertia about any neutral axis x, and y is the distance of the extreme fiber in the direction of the axis of solicitation, *i. e.* the distance between the neutral axis x and that tangent to the cross section which is parallel to x and most remote from it, the distance being measured along the axis of solicitation.

Let $M=Sm$ in which m is called the "specific moment of resistance" of the cross section; it is, in fact, the bending moment which will induce a stress of unity on the extreme fiber.

Now $$I=k^2A$$

in which k is the radius of gyration and A is the area of the cross section.

Let $$k^2\div y=r,\ \therefore\ m=rA,$$

is the specific moment of resistance about x, and when the direction of x varies, r varies in magnitude: r is called the "radius of resistance" of the cross section. The locus of the extremity of r, taken as a radius vector along the axis of solicitation, is called the "kernel."

The kernel is usually defined to be the locus of the center of action of a stress uniformly increasing from the tangent to the cross section at the extreme fiber. It was first pointed out by Jung,* and subsequently by Sayno, that the radius vector of the kernel is the radius of resistance of the cross section measured on the axis of solicitation. This will also appear from our construction by a method somewhat different from that heretofore employed.

Jung has also proposed to determine values of k, by first finding r; and has given methods for finding r. We shall obtain r by a new method which renders the proposal of Jung in the highest degree useful.

The method heretofore employed by Culmann and other investigators has been to find values of k first, and then having drawn the ellipse of inertia to construct the kernel as the locus of the antipole of the tangent at the extreme fiber. The method now proposed is the reverse of this, as it constructs several radii of the kernel first, then the corresponding radii of gyration, and from them the ellipse, and finally completes the kernel. In the old process there are inconvenient restrictions in the choice of pole distances which are entirely avoided in the new process.

Let the cross section treated be that

* "Rappresentazioni grafische dei momenti resistenti di una sezione piana." G. Jung, Rendiconti dell' Instituto Lombardo, Ser. 2, t, IX, 1876, No. XV. "Complemento alla nota precedente." No. XVI.

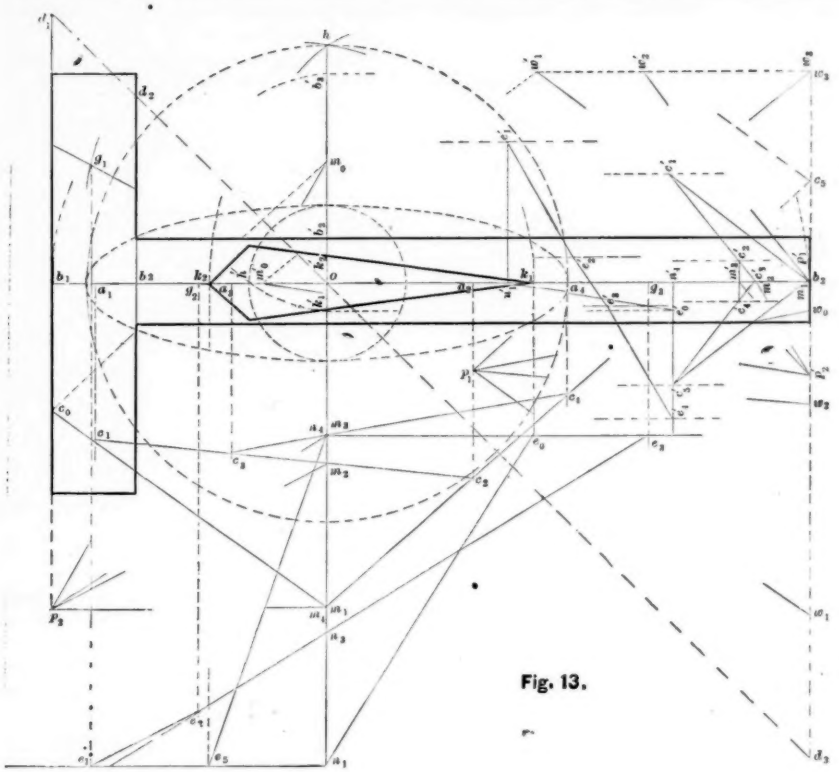


Fig. 13.

of the T rail represented in Fig. 13, which is $4\frac{1}{2} \times 2\frac{1}{2}$ inches and $\frac{1}{2}$ inch thick. We have selected a rail of uniform thickness in order to avoid in this small figure the numerous lines needed in the summation polygon for determining the area; but any cross section can be treated with ease by using a summation polygon for finding the area.

To find the center of gravity, let the weights w_1w_2 and w_2w_3, which are proportional to the areas between the verticals at b_1b_2 and b_2b_3 be applied at their centers of gravity a_1 and a_2 respectively; then the equilibrium polygon c_1c_2, having the pole p_1, shows that o is the required center of gravity.

Let the area b_2b_3 be divided into two parts at o, then w_2w_0 and w_0w_3 are weights proportional to the areas b_2o and ob_3 respectively; and $c_1c_0c_4$ is the equilibrium polygon for these weights applied at their centers of gravity a_0 and a_4.

The intercepts mm have been previously shown to be proportional to the products of the applied weights by their distances from the center of gravity o.

We have heretofore spoken of these products as the moments of the weights about their common center of gravity o. But the weights in this case are areas and the product of an area by a distance is a volume. Let us for convenience call volumes so generated "stress solids." The elementary stress solids obtained by multiplying each elementary area by its distance from the neutral axis will correctly represent the stresses on the different parts of the cross section, and they will be contained between the cross section and a plane intersecting the cross section along the neutral axis and making an angle of 45° with the cross section.

If b_1b_3 is the ground line, b_1b_3 and d_1d_3 are the traces of the planes between

which the stress solid lies on a plane at right angles to the neutral axis.

The distances of the centers of gravity of the stress solids from o are also the distances of the points of application of the resultant stresses, and the magnitude of the resultant stresses are are proportional to the stress solids. The stress solids may be considered to be some kind of homogeneous loading whose weight produces the stress upon the cross section. The moment of inertia I is the moment of this stress with respect to o.

Now the intercept m_2m_1 represents the weight of the stress solid whose profile is of_2d_2. Its point of application is g_2, if $og_2=\frac{2}{3}ob_2$. Similarly the weight m_3m_2 has its point of application at g_3 if $og_3=\frac{2}{3}ob_3$. And the weight m_1m_2 is applied in the vertical through g_1; for the profile of this stress solid is the trapezoid $b_1b_2d_2d_1$, and g_1 is its center of gravity found geometrically. In case the area is divided into narrow bands parallel to the neutral axis the points of application coincide sensibly with the centers of gravity of the bands.

Now take any pole p_2 and construct a second equilibrium polygon ee due to the stress solids applied in the verticals through $g_1g_2g_3$.

The last two sides e_1n_1 and e_2n_4 are necessarily parallel and have their intersection at infinity, for the total stress is a couple.

The intercept n_1n_4 is not drawn through the common center of gravity of the stress solids, *i.e.*, it is not an intercept on the line of the resultant stress, but since parallels are everywhere equidistant this intercept is proportional to the moment of the stresses about their center of gravity; in other words n_1n_4 when multiplied successively by the two pole distances would be I. We shall not need to effect the multiplication.

Prolong c_1m_1 to c_0 on the tangent to the extreme fiber and draw $c_0m_0 \parallel p_1w_2$, then m_1m_2 represents the product of the total weight-area w_1w_2 by $ob_1=y$ the distance of the extreme fiber, or m_1m_0 is proportional to the volume of a stress solid whose base is the entire cross section and whose altitude is $b_1d_1=ob_1$.

Suppose this stress to be of the same sign as that at the right of o, let us combine it with the stress already treated. Its point of application is necessarily at o, and its amount is m_1m_0 if measured on the same scale as the other stresses. Draw $n_1e_0 \parallel p_2m_0$, then is k_1 on the vertical through e_0 the point of application of the combined stresses. But the combined stresses amount to a stress whose profile is included between d_1d_2 and a horizontal line through d_1, *i.e.* to a stress uniformly increasing from b_1 to b_2; hence k_1 is a point of the kernel as usually defined.

If c_1m_4 be prolonged to c_0 and we draw $c_0m_0 \parallel p_1w_1$, then m_4m_0 (not shown) is the weight of a stress solid of a uniform depth b_2d_2 over the entire cross section; and if we draw $n_4e_0 \parallel p_2m_0$, then will k_2 on the vertical through e_0 be also in like manner a point of the kernel, *i.e.* the point of application of a stress uniformly increasing from b_2 to b_1.

But now let us examine our construction further in order to gain a more exact understanding of what the distances $r_1=ok_1$ and $r_2=ok_2$ are.

We have shown that m_1m_0 represents the product of the area of the cross section by the distance ob_1 of the extreme fiber, *i.e.* the quantity Ay_1; but n_1n_4 represents the moment of this weight when applied at k_1, *i.e.* the product Ay_1r_1. Also as previously shown n_1n_4 represented I on the same scale, hence

$$I=Ay_1r_1, \text{ but } I=Ak_1^2 \therefore r_1=k_1^2 \div y_1$$

and r_1 is the radius of resistance previously mentioned.

In order to determine the radius of gyration k_1, which is a mean proportional between r_1 and y_1, describe a circle on b_1k_1 as a diameter intersecting mm at h then $oh=k_1$ the semi-axis of the ellipse of inertia conjugate to mm as a neutral axis. The accuracy of the construction is tested by using b_2k_2 as a diameter and finding the mean proportional between ok_2 and ob_2. It should give the same result as that just obtained. In our Fig. both circles intersect at h.

It is known from the symmetry of figure of the cross section that k_1 is one of the principal axes.

In similar manner we construct the radius of resistance, etc., when b_1b_2 is taken as the neutral axis.

Knowing before hand that this line passes through the centre of gravity, we have taken the weights of the area above it in two parts, viz.: that extend-

ing from b_1b_2, and that from b_2b_3, and we have taken $w_1'w_2'$ and $w_2'w_3'$ respectively, as the weights of these. Choose any pole p_1' and draw the equilibrium polygon $c'c'$: use its intercepts $m'm'$, which represent the weights of stress solids, as weights and with any pole p_2' construct the second equilibrium polygon $e'e'$ on the verticals through the points of application of the stresses. Also find $m_1'm_0'$ the product of the total area by the distance of the extreme fiber and make $n_1'e_0' \parallel p_2'm_0'$; then is k_1' which is on the same vertical as e_0' a point of the kernel, and $ok_1'=r_1'$ the radius of resistance. Use $k_1'b_3'$ as a diameter, then is $oh'=k_1'$ the radius of gyration, for $k_1'^2=r_1'y_1'$. With these two principal axes thus determined, it is possible at once to construct the ellipse of inertia. In any case it will be possible to determine the direction of the axis of solicitation corresponding to any assumed neutral axis by actual construction, it being simply necessary to find the line through o upon which lie the points of application of the positive aad negative stresses considered separately. These axes being conjugate directions in the ellipse of inertia, when we have found the radii of resistance in those two directions we can at once obtain the corresponding radii of gyration which are conjugate semi-diameters, and so draw the ellipse.

After the ellipse is drawn the kernel can be readily completed by making r in every direction a third proportional to the distance of the extreme fiber and the radius of gyration.

We are assisted in drawing the kernel by noticing that to each straight side of the cross section there corresponds a single point in the kernel, and to each non-re-entrant angular point a side of the kernel, these standing in the mutual relation of polar and anti-pole with respect to the ellipse of inertia, as shown by the equation $k^2=ry$.

In Fig. 13 the point k_1 corresponds to the left hand vertical side, the point k_2 to the right hand vertical side, and the sides k_1k_1', k_2k_2' to the angular points at the upper and lower extremities of the left side respectively, while the points $k_1'k_2'$ at the very obtuse angular points of the kernel correspond to the upper and lower horizontal sides of the flange. The two remaining angular points of the kernel correspond to tangent lines when they just touch the corners of the flange and web, while the intermediate sides correspond to the angles at the extremities of these lines.

KERNEL, MOMENTS OF RESISTANCE AND INERTIA: FRAME PENCIL METHOD.

Let the cross section treated be that shown in Fig. 14, which is nearly that of a 56 lb. steel rail, the difference consisting only in a slight rounding at the angles.

Let the cross section be divided by lines perpendicular to the axis of symmetry bb at b_2, b_3, etc., then the partial areas and the total area may be found by a summation polygon.

Take c as the common point of the rays through b_1b_2, etc., and make 01, 02, etc., proportional to the mean ordinates of the areas standing on the bases b_1b_2, b_2b_3, etc. respectively. Draw $s_1u_1 \parallel cb_2$, $s_2u_2 \parallel cb_2$, etc., then will the segments of the line uu represent the respective partial areas, and u_1u_7 will represent the total area.

Divide the vertical line ww into segments equal to those of the line nn, then is ww the weight line for finding the center of gravity etc. of the cross section. Let a_1, a_2, a_3, etc., be the centers of gravity of the partial areas, and let v be the vertex of a frame pencil whose rays pass through these centers of gravity. Draw the equilibrating polygon dd with its sides parallel to the rays of this frame pencil, then the ray vo parallel to the closing side yy of the equilibrating polygon determines the center of gravity o of the cross section, according to principles previously explained.

It will be convenient to divide the cross section into two parts by the vertical line oi, which we shall take as the neutral axis. The partial areas b_2o and ob_4 have a_2' and a_2'' as their centers of gravity. Make $s_2u_0 \parallel co$, then w_0 which corresponds to u_0, divides the weight line into two parts, representing the areas each side of the neutral axis, and the polygon dd can be completed by drawing $d_0d_2 \parallel va_2'$ and $d_0d_4 \parallel va_2''$. It has been previously shown that the abscissas yd represent the sum of the products of the weights (*i.e.* areas) by

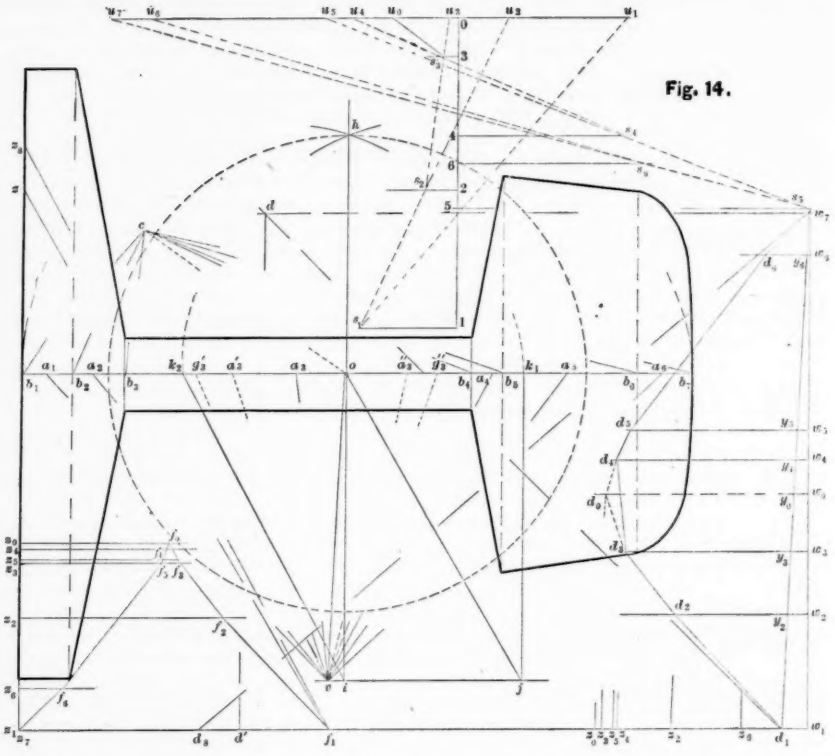


Fig. 14.

their distances from o; and any single product is the difference of two successive abscissas. Project the lengths yd upon the horizontal zz by lines parallel to yy, then the segments of zz represent the products just mentioned. But these products are the stress solids or resultant stresses before mentioned. Hence zz is to be used as a weight line and is transferred to a vertical position at the left of the Fig. The points of application of the resultant stresses may without sensible error be taken at the centers of gravity a_1a_2, etc., of the partial areas except in case of the segments of the web on each side of o. For these, let $og_3' = \frac{2}{3}ob_3$, and $og_3'' = \frac{2}{3}ob_4$, then g_3' and g_3'' are the required points of application.

Now with the weight line zz, which consists partly of negative loads, and with the same vertex v construct the second equilibrating polygon ff, then z_1f_1 represents the moment of inertia of the cross section, it being proportional the moment of the resultant stresses about o. It is seen that the sides f_3f_0 and f_0f_4 are so short that any small deviation in their directions would not greatly affect the result, and that there would therefore have been little error if the resultant stresses in the web had been applied at a_3' and a_3''.

Again, draw $dd_1 \parallel vb_1$, then the horizontal line dw_7 $(=d_1d')$ represents ay_1, the product of the total weight w_1w_7 (*i. e.* the total area of the cross section), by the distance of the extreme fiber $ob_1 = y_1$. Use this as a stress solid or resultant stress applied at o and having a weight $zz_1 = d_1d'$, and draw $oj \parallel zf_1$, j being at the same vertical distance from bb as v is; then is k_1, which on the same vertical at j, a point of the kernel. For k_1 is such a point that the product of ok_1 $(=r_1)$ by the weight $zz_1 (= Ay_1)$ is $z_1f_1 = I$

on the same scale as I was previously measured.

Similarly draw $v_2 d_8 \parallel v b_7$ and make $z_8 z_1 = d_1 d_8$; also draw $ik_2 \parallel f_1 z_8$: then is k_2 another point of the kernel as appears from reasons like those just given in case of k_1.

Use $b_1 k_1$ as a diameter, then oh is a semi-axis of the ellipse of inertia. The same point h should be found by using $k_8 b_7$ as a diameter. Another semi-axis of the ellipse of inertia with reference to bb as a neutral axis, and conjugate to oh can be determined, using the same partial areas, by finding the centers of gravity and points of application of the stresses of the partial areas on one side of bb, the process being similar to that employed in Fig. 13, except in the employment of the frame pencil instead of the equilibrium polygon.

It is to be noticed that the closing side $f_1 z_1$ of the second equilibrating polygon ff is parallel to a resultant ray which intersects bb at infinity, the point of application of the resultant of the applied stresses, *i. e.* the stresses form a couple.

When the ellipse of inertia has been found by determining the magnitude and direction of two conjugate axes, the kernel can be readily completed as has been shown in connection with Fig. 13.

SUPPLEMENTARY NOTE TO THE "NEW CONSTRUCTIONS IN GRAPHICAL STATICS."*

Attention should be directed to the two senses in which M is used in our fundamental formulae.

In equation (3) the primary signification of M is this: it is the numerical amount of the bending moment at the point O; and if this magnitude be laid off as an ordinate, y_m is the fraction or multiple of it found by equation (3).

Now M assumes, in the equations (3), (4), (5) and (3'), (4'), (5'), a slightly different and secondary signification; viz., the intensity of the bending moment at O. The intensity of the bending moment is the amount distributed along a unit in length of a girder, and may be exactly obtained as follows:

$$M = \int_x^{x+1} M dx, \quad \therefore \Sigma_o^x (M) = \int_0^x M dx.$$

In this secondary sense M is geometrically represented by an area one unit wide, and having for its height the average value which ordinate M, as first found, has along the unit considered.

Thus the M used in the equations of curvature, bending and deflection is one dimension higher than that used in the equation expressing the moment of the applied forces; but the double sense need cause no confusion, and is well suited to express in the shortest manner the quantities dealt with in our investigation.

Furthermore, in case of an inclined girder such as is treated in Prop. V, if the bending moment M, which causes the deflection there treated, be represented, it must appear as an area between two normals to the girder which are at the distance of one unit apart.

In order to apply Prop. V to inclined and curved girders, such as constitute the arch with entire exactness, one more proposition is needed.

Prop. If weights be sustained by an inclined girder, and the amount of the deflection of this girder, which is caused by the weights, be compared with the deflection of an horizontal girder of the same cross section, and of the same horizontal span, and deflected by the same weights applied in the same verticals; the vertical component of the deflection of the inclined girder, at any point O, is equal to the corresponding vertical deflection of the horizontal girder, multiplied by the secant of the inclination.

For the bending moment of both the inclined girder and the horizontal girder is the same in the same vertical, but the distance along the inclined girder exceeds that along the horizontal girder in the ratio of the secant of the inclination to unity; hence the respective moment areas have this same ratio; therefore the deflections at right angles to the respective girders of their corresponding points are in the ratio of the square of the secant to unity; and the vertical components of the deflections are therefore in the ratio of the secant of the inclination to unity.

In applying this proposition to the graphical construction for the arch, it will be necessary to increase the ordinate of the moment polygon at each point by multiplying by the secant of the inclination of the arch at that point. This is easily effected when the ordinates are vertical by drawing normals at each point of the arch; then the distance along the normal whose vertical component is the bending moment is the value of M to be used in determining the deflection.

In the arches which we have treated the rise is so small a fraction of the span that the secant of the inclination at any point does not greatly exceed unity; or, to state it otherwise, the length of the arch differs by a comparatively small quantity from the actual span. It is a close approximation under such circumstances to use the moments themselves in determining the deflections; and we have so used them in our constructions. A more accurate result can be obtained by multiplying each ordinate by the secant of the inclination of the arch at that point to the horizon.

* See Van Nostrand's Engineering Magazine, Vol. XVI.

LIGHTHOUSE MEMORANDA.

By Captain W. A. JONES, U. S. E., Engineer, Sixth Lighthouse District.

Written for Van Nostrand's Magazine.

I.

RANGE LIGHTS.

A range of lights affords a guide for leading vessels through channel-ways that has the merit of simplicity and precision. It is customary to place two lights on the line of prolongation of the channel, to be marked with the horizontal distance between them, so adjusted to the distance to any point of the channel as to make an ordinary departure from the line at once apparent by the separation of the verticals through the lights. Their angular distance from each other in a vertical plane, measured from the extreme outward point where a vessel would commence using the range, is fixed so as to prevent them from apparently coalescing under the influence of the phenomenon of irradiation.

The rear light of a range should never be obscured, because there are so many chances of its becoming accidentally obscured or extinguished, an event which might lead to disaster. For a similar reason, it would be preferable not to allow the two lights to coalesce at any point of the range.

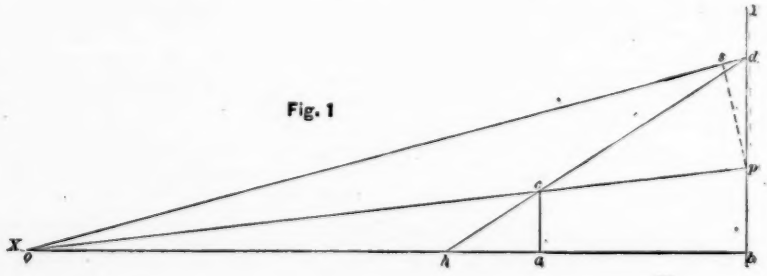
The apparent size of luminous objects at night is greater than the actual, in consequence of what is termed irradiation. This phenomenon probably proceeds (1) from atmospheric reflection from the field adjacent to the line of sight, and (2) from the effect of the violent contrast between the light and its dark background. This produces such a vivid image upon the retina of the eye that the molecular excitement of the nerves probably extends beyond the normal outlines of the image. It is variable in amount, increasing with certain conditions of the atmosphere and of the eye, and decreasing with the distance. It can be reduced by the use of glasses, in proportion to their power.

Unless the outlines of a luminous body subtend a visual angle, large enough to render a surface bounded by it visible by day, its outline cannot be visible at night. The luminous object as seen will be made up mostly of irradiation rays. The visual angle of the sun's diameter is large enough to enable its outlines to be seen. The same is true of the moon. With the planets, it is too small for the naked eye, but large enough for a telescope. In the case of the fixed stars, it is too small for even the most powerful glasses.

The visual angle between two range lights—the rear showing above the front—estimated from points along the range line, is a variable function. It increases in value from a minimum $=0$ at a distance $=\infty$ from the rear light up to a maximum at a point not far from the front light, from whence it rapidly diminishes to 0 at the point where the angle line is intersected by a line through the two lights.

This subject is susceptible of analytical discussion as follows:

Fig. 1



Let bX be the axis of X positive towards X.

Let bY be the axis of Y positive towards Y.

Let ac be the front beacon.

Let bd be the rear beacon.

Let bo be the horizon line through b.

Let o be any position, upon the range of observer's eye.

Let V$=dop$ represent the visual angle between the lights.

Let $bo=x$ and $bp=y$.

Draw ps the opening of the visual angle v at p.

Let p represent the angle difference between ops and 90° at p.

Then for all values of v less than 20 minutes, we will have angle p less than 10 minutes and cos. $p=1$, also; tan. V$\times op=ps$, or, tan. V$=\frac{ps}{po}$.

Now $ps=rpd$, r being deducible after the assumption of x.

Represent $pb+bs=pb+rpd$, by a and place gx for po, q being deducible after the assumption of x.

We then have $ps=a-y$ and

$$\text{tan. V}=\frac{a-y}{qx} \quad . \quad . \quad . \quad (1)$$

From triangles pob and coa we have after placing c for ac

$$x : y :: x-ab : c$$

Placing l for ab, we have

$$y=\frac{cx}{x-l} \quad . \quad . \quad . \quad . \quad (2)$$

Substituting in equation (1) we have

$$\text{tan. V}=\frac{(a-c)x-al}{q(x^2-lx)} \quad . \quad . \quad (3)$$

From this equation the value of v at any point can be obtained by assuming the proper value for x.

It is evident that v is not a uniformly varying function. To ascertain the location of its maximum and minimum values, resume equation (3) and place m for $a-c$. Then differentiate this value at tan. v and make the first differential coefficient equal to o. This gives

$$\frac{2alx-mx^2-al^2}{q(x^2-lx)(x^2-lx)}=o \quad . \quad . \quad (4)$$

This equation is of the general form

$$f(ax^4+bx^3+cx^2+dx+e)=o$$

which has four real roots corresponding to four maximum and minimum states of the function tan. V.

Factoring (4) we obtain

$$\frac{1}{q(x^2-lx)(x^2-lx)}=o \quad . \quad . \quad (5)$$

and

$$mx^2-2alx=-al^2 \quad . \quad . \quad (6)$$

From (5), $x=\pm\infty$. These two values correspond to minimum states of the function tan. v. They give in (3) tan. $v=o$ or $v=o$. That is to say, the visual angle is equal to o at the distances of $\pm\infty$ from the rear light at b.

From (6) we have

$$x^2-\frac{2al}{m}x=-\frac{al^2}{m}$$

The roots of which are

$$x=+\frac{al}{m}\pm\sqrt{-\frac{al^2}{m}+\left(\frac{al}{m}\right)^2}$$

Two of these are real and positive, and two are imaginary depending upon the value of l, the two real roots correspond to maximum states of the visual angle v whose value may be found by substituting in (3). Resuming the values

$$x=+\frac{al}{m}\pm\sqrt{-\frac{al^2}{m}+\left(\frac{al}{m}\right)^2}.$$

and replacing for m the term for which it was substituted we have

$$x=+l\left\{\frac{a}{a-c}\pm\sqrt{-\frac{a}{a-c}+\left(\frac{a}{a-c}\right)^2}\right\}$$

The first of these values of x is greater than l and the corresponding maximum value of v falls on the range beyond the front light.

The second value is less than l and greater than o for all values of $c<a$, and the corresponding value of v falls between the two lights.

There remains to be considered a minimum value $v=o$, of the visual angle that is not accounted for by equation (4). It occurs at the point h, where the line through the two lights intersects the range line bo. Under this condition, however,

$$bp=bd, \text{ or } y=a.$$

Which in (1) gives

$$\text{tan. } v=o.$$

a minimum state of the function.

Now equation (4) is derived from (1) by substituting therein a value for y, hence the present condition is such that (4) can have no existence, and therefore it should not account for this particular state of the function.

In the foregoing discussion, the curvature of the earth is not taken into account, since the results will be found sufficiently accurate for practical purposes, and the general conclusions are not affected by it.

Owing to the apparent increase in size of a light affected by irradiation, two lights of a range will coalesce unless they be displayed under quite an appreciable visual angle. Upon the establishment of this angle at a minimum consistent with the separate distinction of each depends, very largely, the economical construction of rear beacons, especially for ranges that extend to long distances from the lights. Indeed, beyond even a moderate distance, the conditions require the construction of a rear beacon of extraordinary height. On flat coasts the difficulty can be overcome and ranges of extreme length established by using for the rear beacon twin towers disposed symmetrically on either side of the range line, so as to show a *horizontal* visual angle between the front light and each of the rear lights on the starboard and port hand. The rear structures can then be made at minimum height. This is an important consideration when we consider that the cost of constructing towers increases very rapidly with increments of altitude.

The three lights can be of the same color, as no practical difficulty will be experienced in distinguishing the one in front from those in rear.

The minimum visual angle can only be determined by a careful series of experiments, so as to introduce all possible elements of its variation. In the French Lighthouse service numerous experiments have been made, and the result, as announced by Reynaud, is that angles of 15 minutes for the 1st, 2d, and 3d orders, and 8 minutes for those of lower orders can be relied upon. In the practice of the U. S. Lighthouse Board, angles of 3 and $3\frac{1}{2}$ minutes have been found sufficient for range lights. Some observations recently made by me upon the two first order lights at Nevesink Highlands, New York Harbor, point to a possible reduction below these figures, and also indicate that the effect of irradiation decreases with the distance. This latter would seem almost obvious, since the rays reflected from the field adjacent to the line of sight should be rapidly dispersed with increments of distance, and as the power of a light decreases under the same condition, its contrast effect upon the retina of the eye should be correspondingly reduced.

The minimum visual angle should be established for the extreme outside point, where the range may be used.

Where the channel is sufficiently wide, the rear light is sometimes allowed to coalesce with the front along the extreme outer portion of the range, but the range line must be so disposed as to permit the requisite angle for separate distinction to be opened on either hand before the border shoal is reached. The following discussion will illustrate:

The figure is on a plane through the vertical line of the front light and perpendicular to the vertical plane of the range line.

Let a be the position of the front light.

Let b be the position of the rear light projected upon this plane, by a line through the point on the range where the visual angle is a minimum for separate distinction.

Let $b_1 \ldots b_2 \ldots b_3 \ldots$ be assumed positions of b under a smaller angle.

Let $b\beta \ldots b_1\beta_1 \ldots b_2\beta_2 \ldots$ be approximate positions of the lines, over which the rear light will apparently move as observer's eye passes to same side of range line.

Let $\beta_1 \ldots \beta_2 \ldots \beta_3 \ldots$ be points on these lines where it will give a visual angle sufficient for separate distinction.

Let $v \ldots v_1 \ldots v_2 \ldots$ represent the visual angle when the rear light is at $b \ldots b_1 \ldots b_2 \ldots$ respectively.

Let d represent the distance from the front beacon to the assumed position of observer's eye on the range line.

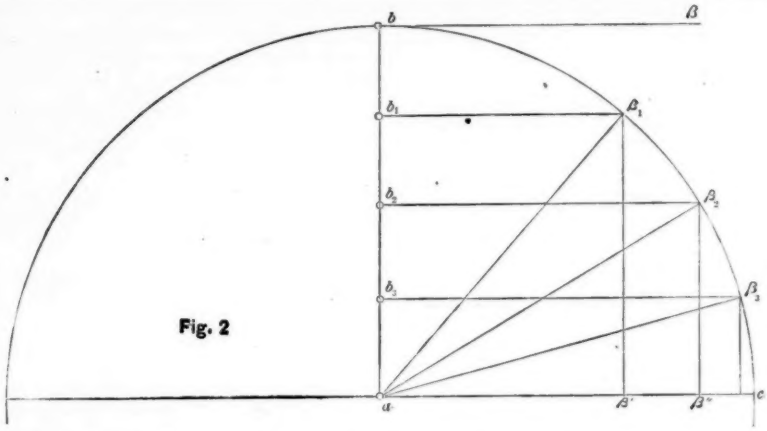


Fig. 2

Now, at this distance we have within the limits of practice

$$ab = \text{tan. V.}$$

Whichever of the above positions be assumed for the rear light the distances $ab_1 \ldots ab_2 \ldots$ will be equal to the sines of angles of which $b_1\beta_1 \ldots b_2\beta_2 \ldots$ are the cosines, and therefore the latter can be obtained from the known relation between sine and cosine by assuming values for $ab_1 \ldots ab_2 \ldots$ Thus: if $ab_2 = \frac{1}{2}ab$ the value of $b_2\beta_2$ will be 0.866 ab. Knowing $b_1\beta_1 \ldots$ etc., the width of the belt at any point of the range outside of which the two lights will appear separately distinct can be obtained as follows:

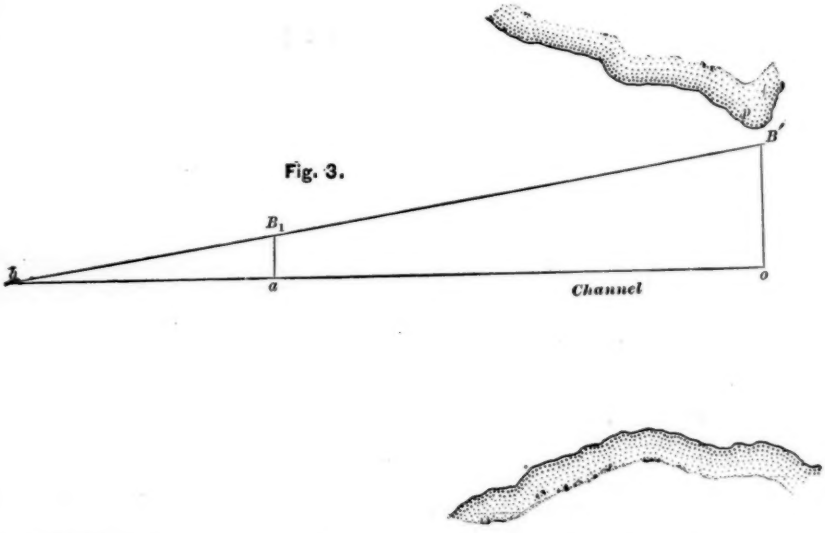


Fig. 3.

In this figure, which is a plan of the range bo, a is the position of the front light, b that of the rear light, o the position of the observer's eye on the range light, and p the point of the shoal on the starboard hand going towards the lights.

Take the triangle $bo\beta'$ in the plane through the front light and the line $o\beta'$

which is perpendicular to bo. In this triangle we have

$$ba : bo : : a\beta_1 : o\beta'$$

But $a\beta_1 = b_1\beta_1$ (Fig. 2)

Therefore $$o\beta' = \frac{bo \times \beta_1 b_1}{ba}$$

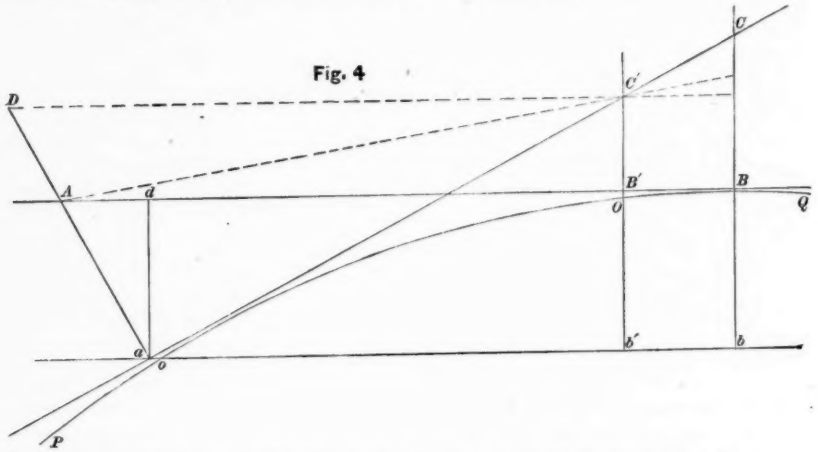
The following example of one of the two ranges proposed for Port Royal Harbor, South Carolina, will illustrate the general subject:

POQ . . . Curve of the earth's surface.

OC′ . . . Front Beacon.

BC . . . Height on rear Beacon intercepted by ray of light aC′ from observer's eye at a.

Fig. 4



Do is the vertical at a, AB is the horizon line through B, $ab'b$ is parallel to AB, ad is perpendicular to AB, BC and OC′ are prolonged to b and b' on ab.

oa=15 feet=height of observer's eye above the sea.

DC′a=Aad=Dip of the horizon.

Ao=Curvature correction.

ad=Aa cos. Aad.

Cos. Aad=1,000 for all angles less than 10^m.

Therefore, ad=Aa for all angles less than 10^m.

PARIS ISLAND RANGE (Fig. 4)

Bo=13¾ miles, B′o=12¼ miles, OC′=45′. The value of OC′ is found from the table of corrections for curvature and refraction. B′C′=45′−1.′5=43.′5. Ao = difference of level = 107′. DC′a $=6^m36^s$, therefore ad=Aa. ad=B′b' =Bb=107′−15′=92′ b'C′ = B′C′+B′b' =43.′5+92′=135.′5, ab=Bo×q. ab'= B′o×q. From triangles abC and ab'C′ we have

$$b\text{C} = \frac{ab \times b'\text{C}'}{ab'} = \frac{\text{B}o \times q \times b'\text{C}'}{\text{B}'o \times q} = 152.'1$$

BC=bC−Bb=152.′1−92′=60.′1.

A visual angle of 3 minutes has an opening of 63′ at a distance of 13¾ miles, therefore we have

Height of rear beacon = 60.′1+63′ = 123.′1 above the sea level.

II.

NUMERICAL DISTINCTION OF LIGHTS AND TOWERS.

It is quite desirable that some means of distinction should characterize any system of lights so that as soon as, or shortly after, a vessel comes in sight of any one, either by day or night, its locality will be clearly announced. Such a system naturally separates itself into two parts, viz., day-marks (1) and lights (2).

DAY MARKS.

The most effective means of marking a tower so that it may be distinguished and characterized by day, is by showing upon its surface a certain marked color or contrast of colors. Experience shows and the laws of optics also teach us, that for long distances, the only satisfactory colors for this purpose are black and

white. There is a varying limit beyond which the light from colored objects ceases to be reflected, and the objects will thereafter appear black. White rays are generally thrown as far as the outlines of a tower will show, but not if they are reflected from a surface in strong shadow.

Within the limits of its range, red is a very strongly marked color.

Experience further shows that color contrasts on towers are most readily observed when shown in alternating horizontal bands. The minimum width of a band will be the diameter of the tower where it is placed. A black band of width equal to the diameter of the tower will appear as soon as the outlines of the tower become visible, provided, the distance be not so great or the conditions such that the white rays from the adjacent contrast bands have not been dispersed by the atmosphere.

With the foregoing considerations in view, I have arranged the following system for coloring towers as day-marks:

SYSTEM FOR COLORING TOWERS.

(*Represent white by* 1 *and black by* 2.)

(1)	2	bands	at top of	minimum width	1-2
(2)	2	"	"	"	2-1
(3)	3	"	"	"	2-1-2
(4)	3	"	"	"	2-1-1
(5)	3	"	"	"	2-2-1
(6)	3	"	"	"	1-2-1
(7)	3	"	"	"	1-2-2
(8)	3	"	"	"	1-1-2
(9)	4	"	"	"	1-2-1-2
(10)	4	"	"	"	1-1-2-2
(11)	4	"	"	"	1-2-2-1

etc., etc.

($n-1$).... .....all black.

(n).....all white.

No occasion need be found for using more than four bands.

The lantern and gallery should always be black when the background is sky.

The bands are all at the top of the tower and are enumerated from the top downwards. Below the bottom band, the tower should be colored in contrast with it, thus: black, if the band be white, and white, if the band be black.

Selection from the above list will have to be guided and varied by the background upon which the tower is projected. It affords ample variation for the most extended coasts, since repetition is perfectly allowable beyond reasonable distances.

For short range harbor lights, ample distinction can be secured by coloring the towers all red, or white, or black.

LIGHTS.

The most satisfactory light is a fixed white varied by flashes. The flashes should be white, but may be red where the range is not great. A flash can be seen much farther and is picked up with more readiness than a fixed light, but it is difficult to keep the eye fixed upon it when there is much interval or any considerable motion of the vessel. This difficulty is obviated by associating a fixed light with it. A combination is thus afforded that can be observed with ease and precision. Simple flashing lights that flash at intervals exceeding 1.5 minutes are somewhat objectional as it is rather difficult to keep the eye fixed upon them at long range in rough weather.

It should be observed, that at long range a red light can be distinguished by its color only with extreme difficulty and often not at all.

These considerations lead to the following system for the numerical distinction of lights.

SYSTEM OF LIGHTS.

(1)	Fixed	varied by	single flashes	1, 1, 1
(2)	"	"	double "	2, 2, 2
(3)	"	single and double flashed		1-2, 1-2
(4)	"	"	"	2-1, 2-1
(5)	"	"	"	1-2-1, 1-2-1
(6)	"	"	"	1-2-2, 1-2-2
(7)	"	"	"	1-1-2, 1-1-2
(8)	"	"	"	2-1-2, 2-1-2
(9)	"	"	"	2-1-1, 2-1-1
(10)	"	"	"	2-2-1, 2-2-1
(11)	"	"	"	1-2-12, 1-2-1-2,

etc.

The different apparatus of this system can be timed so as to show the flashes and the long and short darks at the same intervals of time, thus affording perfect uniformity and simplicity. The system is capable of producing an ample number of variations without going beyond four-group flashes.

In most instances the group numbers of both the flashes and colored bands at a tower can be the same.

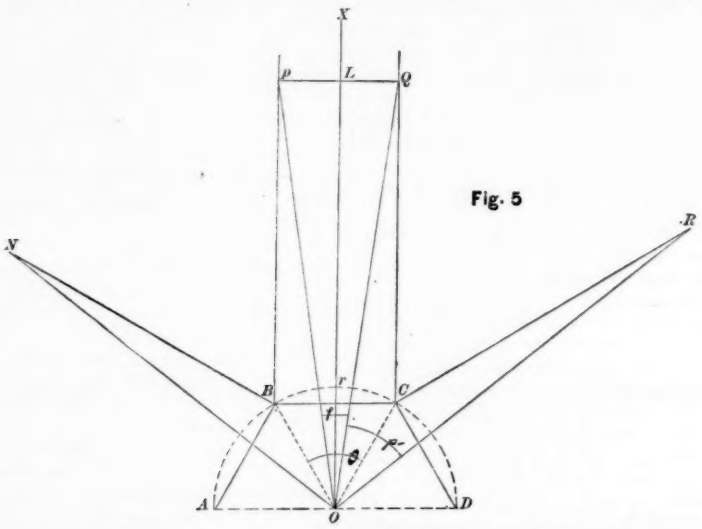


Fig. 5

III.

RELATIVE DURATION OF FLASHES AND ECLIPSES IN REVOLVING LIGHTS.

Let ABCD . . . be the plan of a portion of a flashing lens apparatus of any number n of sides, the flashes and eclipses being produced by the revolution of the whole apparatus about its axis at O.

On the line OX, perpendicular to BC, take L at any distance x from the light.

Draw BP and CQ perpendicular to BC and CR perpendicular to CD. Draw through L a parallel to BC and from P and Q where it intersects BP and CQ, draw PO and QO. Also take OR=OQ.

Then PBCQ will be part plan of one of the spaces covered by the flashes, and QCR part plan of one of the spaces covered by the eclipses as the apparatus revolves about its axis. This, of course, supposes the light at O to be concentrated in a point.

Let $\theta=\text{BOC}=\frac{360^\circ}{n}$, and $\psi=\text{POQ}$ be any angle interval of the flash at any point. Also let $\psi'=\text{QOR}$ be the corresponding angle interval of the eclipse. The angle BOC=QCR=POR,

or, $$\theta=\psi+\psi' \quad . \quad . \quad . \quad (1)$$

From triangle POL, we have tan. $\text{POL}=\frac{\text{PL}}{\text{OL}}$.

Placing a for $\text{PL}=\frac{1}{2}\text{PQ}=\frac{1}{2}\text{BC}$, and representing Lr by x' and Or by R, Or being the radius of the apparatus=OC, we have

$$\text{tan.}\ \tfrac{1}{2}\psi=\frac{a}{x}=\frac{a}{\text{R}+x'} \quad . \quad . \quad (2)$$

From (1) we have

$$\psi'=\theta-\psi \quad . \quad . \quad . \quad . \quad (3)$$

From (2) it appears that as x increases, ψ decreases until $x=\infty$ when D=o.

When $x=\text{R}$, tan. $\frac{1}{2}\psi=\frac{a}{\text{R}}$, and $\psi=\theta$.

From (3) it is evident that when $\psi=o$, $\psi'=\theta$, and when $\psi=\theta$, $\psi'=o$.

From (2) and (3) we can obtain the value of ψ and ψ' at any distance by assuming x, when the dimensions of the apparatus are known.

The values of ψ and ψ' in seconds of time, or the duration of the eclipse and flash, at any distance from the light, can be obtained by applying to the deduced values the ratio between arc and time, when n and the time of a complete revolution are known. It will be seen from the foregoing discussion, that the duration of the flashes and eclipses of any revolving light varies with the distance of the observer from it, and that the proper method of observing these intervals is to estimate from the begin-

ning of a flash to the beginning of the one next following, or, from the middle of a flash to the middle of the next following. Also, that any reference to the duration of a flash or eclipse should be accompanied by a statement of the distance. A good expression for characterizing the time feature of revolving lights would be: Flashes commence at intervals of * * *

IV.

VERTICALLY PROJECTED LIGHT.

If a lens were so arranged as to throw a portion of the light as a vertical, or nearly vertical, beam, this beam would probably be visible at very great distances, especially in thick or cloudy weather, when the rays would be reflected from the vapor particles at great elevation.

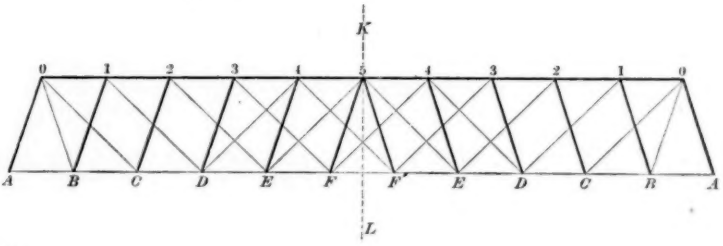
CERTAIN DISCREPANCIES IN THE COMPUTATION OF THE POST TRUSS.

By CHARLES H. TUTTON.

Written for Van Nostrand's Engineering Magazine.

An application of the Graphical Analysis presented by the writer, in this Magazine for Nov., 1877, to the truss below represented, yields some curious facts. In order to avoid diagrams, which any one may construct by paying attention to that article, the results given in this article are arrived at by a calculation exactly in accordance with the graphical method. To show the discrepancies more clearly, I will take a strain sheet of the Watson Mf'g. Co. calculated from their data, and place their results side by side with those obtained in accordance with the graphical method.

It may be proper to state, however,



that from the compound nature of this truss all results must be based on certain suppositions. As the writer cannot agree with Col. Merrill and others who treat the inclined posts as counter braces, the supposition employed will be that the truss may be divided into two simple systems. Considering the truss loaded and the load moving off to the right, the braces, and, in fact all of the truss on the right of the center except the post 5F' is common to both systems. On the left, the first system is composed of posts 5F, 3D, 1B, 0A and connecting braces, and the second of posts 5F', 4E, 2C, 0A and connecting braces. The loading and dimensions are as follows:

Height of truss, 28′6″; No. panels, 11; length of panels, 19.0 ft.; dead load per foot (two trusses), 950 lbs. = 475 per truss; live load per foot (two trusses), 2240 lbs. = 1120 per truss; panel weights per truss, dead, 9025 lbs.; live, 21,280 lbs. By the method of procedure employed in the Graphical Analysis, before referred to, we find the following resulting strains:

STRAINS IN LOWER CHORD.

AB =	50510 lbs.	Watson	50510
BC =	101020 "	"	101020
CD =	171732 "	"	171734
DE =	242444 "	"	242448
EF =	272749 "	"	272754
FF′ =	303054 "	"	303060

IN UPPER CHORD.

01 =	141426	Watson 141428
12 =	222240	" 222244
23 =	262647	" 262652
33 =	303054	" 303060

Showing so far no discrepancy.

STRAINS IN DIAGONAL TIES.

0B =	95824	Watson	95823
0C =	85702	"	85714
1D =	88438	"	85714
2E =	48322	"	51068
3F =	53794	"	56542
4F′ =	16423	"	27370
5E =	27352	"	27370
4D =	3650=16411 before countering.	"	16422

STRAINS IN POSTS.

0A =	159707	Watson	159705
1B =	65922	"	63882
2C =	36022	"	38061
3D =	40098	"	42141
4E =	12243	"	20400
5F =	20389	"	10200

It will be observed that there is a great discrepancy between these results in the web members especially at the center of the truss.

These results are derived from the supposition that when the truss is uniformly loaded, the strain through braces 0B and 0C are at their maximum and the load passing off relieves them, as in the Graphical Analysis.

It shows that when the load throws the maximum strain on 5E that the vertical force at 5, instead of being divided equally between posts 5F and 5F′, sends through 5F′ only $\frac{1}{n}$ of a panel weight (n being the number of panels in the truss) of live load, while all of the remaining stress passes through post 5F.

As to the correctness of this method, it is left to others to judge. It is given here, as I was informed once of a bridge failing under circumstances which this view would indicate as possible, and I regret that I have mislaid the paper which contained its locality.

Referring again to the article quoted, it is but justice to state that the method then employed, and the combination of different loads in one general reaction or "force polygon," was suggested to me by seeing some lectures of Prof. Chas. McMillan, now (I believe) of Princeton College, N. J., and the method was not given as original with myself, but as an improvement (fancied so at least) over already existing, though so far as I am aware, unpublished methods. He also pointed out its generality of application in 1874.

The modification suggested by Prof. Fletcher in *Engineering News* for Jan. 17, 1878, has been employed by myself and others for nearly a year preceding the publication of the article. It was given as a purely graphical method, leaving out many simplifications which were self-evident, in order to make the "modus operandi" clear to a beginner as well as to the more proficient.

THE *Lifeboat Journal* thinks the time has come for a revision of the night signals established by the Merchant Shipping Act, 1873, and defines the principles which, it thinks, should be kept in view in any such revision, in the following sentences:

"(1) It is indispensable that signals of distress should be few in number, and readily distinguishable from all other signals, especially those shown in the night, since persons having to interpret them on the land would, in general, have no code of signals to refer to, but would have to trust their memories alone.

"(2) They should not be of an expensive or unwieldy character, or of a kind requiring skillfulness in their use, or they would not be available for all classes of vessels.

"(3) It would be desirable, as far as possible, to utilize articles already on board rather than to provide new ones unavailable for any other use."

PLOWING BY STEAM.

By D. D. WILLIAMSON.*

Contributed to VAN NOSTRAND'S MAGAZINE.

PERHAPS no branch of engineering has been more fascinating to mechanical engineers than that of steam plowing. The thought of inventing an implement which would supersede the common plow and revolutionize a process which is older than Christianity itself has, for many years, stirred the hearts and brains of ingenious men and incited them to patient labor and extraordinary effort. None have struggled more with this problem or met with greater disappointment than American engineers. The cheapness of our prairie land; the size of our farms; their natural adaptation to steam cultivation; the high cost and uncertainty of labor and many other reasons made it appear probable that this country would bring forth the steam plow and perfect it. The records of the Patent Office show how many men thought they had accomplished it. The fact that, in the year 1870, not a steam plow was practically working in the country proved the value of these patents. From among the many steam plows which were actually tried, and which gave promise of success, the Fawks and the Locher were perhaps the best. Fawks anticipating the prime trouble of all traction engines, viz; that of keeping the driving wheels from being buried by the weight of the engine whilst passing over soft ground, adopted the novel idea of using one driving wheel the entire width of his engine, and to facilitate its turning, shaped this long roller like a barrel, having the outer ends of less diameter than the center. The engine seems to have progressed fairly on dry ground and drew several plows which were hung from a gallows frame in the rear. Inability to generate steam sufficiently, which is the second grand difficulty with traction engines, prevented any continuous plowing. Before the engine could get across the field the incapacity of the boiler would bring the whole to a stand still. The barrel-shaped driving wheel or roller, proved of no use in wet clay. To gain adhesion and prevent its useless revolving as it slipped in the wet soil, stout battens or strips of wood were fastened to the face of the roller so as to grip the earth and prevent the slip. These, however, held so well that the engine had not power enough to turn them. To have gained greater power would have necessitated increased weight and the weight was already sufficient to bury the engine hopelessly at almost every trial. The experiment was, therefore, abandoned. From later experience it is evident that Fawks had only just entered upon his troubles, for he had not worked his system sufficiently to develop the crowd of difficulties which awaited him.

Locher chose a much more favorable field for his operations, viz; the dry soil of California. His engine was more of the usual type of Traction engines, and was fitted with compensating gear which enabled it to turn whilst drawing its load. The details of the engine were, however, very rough. The special feature was the revolving diggers which worked behind, and which were driven from the same shaft as the driving wheels. It was claimed that these diggers helped very materially to propel the engine over the ground. The style of cultivation was, however, very peculiar and raised the objection that the huge clots of earth which were thrown from the diggers were not pulverized, and, consequently, the field was not in a condition to receive the seed. Although Locher deserves great credit for his ingenuity, the early abandonment of his machine was an evident sign of its unfitness for its work. It would have been interesting to have had some trials with the revolving diggers in soft earth. The presumption is that the engine would have stood still whilst the diggers would have dug a trench in which the whole would have settled. Of the more recent attempts may be mentioned, the Parvin motor which was simply the Boydell sys-

* Read before the New York Society of Practical Engineering.

tem, which had been tried and abandoned in England many years ago. Traction was obtained by an engine mounted on a revolving platform, not unlike in appearance to a portable horse power. A series of slats of wood the width of the engine and separated a few inches from each other secured to endless chains, revolved over drums at each end of the engine, and slowly moved the same. The friction was, however, enormous, and the power required to move the large bearing surface which was in contact with the earth, proved, as in Boydell's experiments, out of all proportion to the total power, and, consequently, left too little power for useful work. The plows were arranged in a frame at the rear of the machine somewhat like Fawks, So small an amount of plowing was done by this system that no record is left of the manner in which it overcame the difficulties of continuous plowing. Boydell had hauled plows quite successfully so long as all the conditions were favorable for his machine, but when the question of expense, the quickness of turning, the unevenness of the ground, and the *breakage* were taken into account, the impracticability of the machine was so apparent that it was abandoned. As Parvin's was no improvement on the Boydell system its life seems to have been quite as brief.

The Redmond engine which is a copy of the Bray engine, also patented and abandoned in England many years since, depends for adhesion upon diggers which are pushed out from the center of the drivers and then withdrawn as the wheel revolves, very much like the patent buckets of some of the English side wheel steamships. With the ground just in the right condition they work well enough, but if the soil was hard the whole engine walked on its rim tip-toes very much to their damage. With soft earth the toes or diggers quickly dug holes under the driving wheels until the engine sat upon the ground, when all traction ceased. It was proposed by Redmond to draw some kind of a gang plow behind his engine. The only experiments made public were those in which several men held ordinary plows which were hitched to the engine as to a horse, and which were drawn across the field, but not turned.

There may have been other systems, but it is believed that the foregoing comprises the best of those which were actually in the field.

Dudgeon, Fisher and others had produced quite successful light traction engines which ran well on McAdamised roads, but none of them were designed for the more difficult work of plowing. The great question of maintaining adhesion on slippery fields—of working in soft earth—of keeping up steam to a full working pressure during the entire day—of carrying supplies of fuel and water—of durability—of accurate steerage and rapid turning, had scarcely been entered upon by any of those whose attempts have been named. Naturally with the spasmodic efforts of the engine the great problem of the construction of suitable plans had no chance of solution. The failure of the engines had precluded the necessity for attacking the question of the work they were to do, and engines and plows went down into a common grave together. In the year 1869, I saw a Thomson Road Steamer, with its broad rubber tires draw a train of heavily loaded wagons over a soft wet field in Scotland. I rode upon the engine when it drew the same load through the yielding deep sands on the shore of the Firth of Forth, and when it climbed the steep, slippery streets of the old town of Edinburgh. I spent many days with it striving to find a fault with its peculiar tire, but the more I examined its workings the more I was convinced that its camel-footed, elastic tread solved the great question of maintaining its footing, whilst working in soft soil and drawing plows behind it. Having arranged for the right to work under the American Patents, I imported an engine from Scotland in 1870, and commenced a series of experiments with it. Whilst the rubber tire did all and more than I had expected, I found the difficulty of maintaining steam a most serious drawback. Calling to my aid some of the best engineering talent in the country, I succeeded, in 1871, in producing what was afterwards known as the "Williamson Road Steamer and Steam Plow." The engines were built by the Grant Locomotive Works of Paterson N. J., and were far ahead of anything which had been attempted before in either

hemisphere. Boilers, shafts and gearing of steel, and the exactness in workmanship of the finest express locomotives, gave them the perfection of strength with the minimum of weight. With all the costly experience of the past four years it can be safely said that no more perfect engines could be produced to-day. With their peculiar boilers steam was made with such rapidity that no difficulty was found in maintaining it at 120 lbs. pressure, with the valves wide open and the engines making 300 or 400 revolutions per minute. A brief description of the engine as finally completed may be of interest.

The entire engine which was only 13 feet long by 6 wide, was mounted on three wheels. The drivers which were so placed as to take nearly the whole weight were six feet in diameter, with a tread of 12 inches. The third wheel was about half the size of the drivers, placed at the extreme front in a fork, and being worked by a sector and uneven wheel steered the engine with perfect accuracy and with very little effort. All three wheels had tires of a peculiarly compounded and vulcanized india rubber, made in a single ring 12 inches wide and 5 inches thick. Side flanges prevented these from slipping off, whilst a great number of holes in the tread of the wheel into which the rubber was forced, as the weight was upon it, prevented in a great measure their slipping around. Outside of this rubber tire was a chain of endless steel plates which revolved with the wheel and which sinking into the rubber as it came in contact with the ground preserved it from all harm. It may then be properly mentioned that whilst many supposed that the rubber would be quickly worn out, no difficulty was ever found on that point, and a set of tires which had run in hard work over all kinds of roads and fields, over 3,000 miles, when taken off and examined were scarcely marked, and there was no reason to doubt but that they would outlast the boiler and engines.

The vertical boiler which was of steel, was 3 feet in diameter with 120—1½ inch tubes, and with the most perfect proportion of water and steam space. It supplied steam to two 6×10 inch cylinders, the valves of which were wrought with a link. The throttle valve and reversing handle were within handy reach of the engineer as he worked the steerage. On the crank shaft was a pinion which geared into a spur wheel on an intermediate shaft, and on the ends of the latter shaft were sliding clutch pinions which engaged racks bolted to the inside of the drivers. These clutch pinions were worked by handles at the side of the engineer's seat. The crank shaft was provided with the same arrangement of clutch pinions, thus giving the engine two speeds. The quick speed which was about 6 miles per hour, was for road service—the drivers turning once to every six revolutions of the engine. The slow speed for plowing was 2½ to 3 miles, requiring 18 revolutions of the crank shaft to 1 of the drivers. The latter gave the enormous tractive force of about 8000 lbs., equal to that of say 40 horses. Either driving wheel could by the same handles be entirely disengaged, so that the engine could turn in its own length. Tanks which hold 300 gallons of water and bunkers containing half a ton of coal were conveniently disposed. The weight of the engine was six tons, and whilst ample strength was secured, there was not a superfluous fund of metal. This is an important statement, for it is a common belief that a traction engine for drawing plows, can be made as light as a fire engine.

Two of the engines were sold to parties in Great Britain and are being worked as road engines. Being of American build they have naturally been very closely criticised, and it has been freely conceded that no such perfect engines have been made in that country.

A number of plows were tried. The latest of which made after two years of hard experience, consisted of six steel plows on a diagonal beam mounted on a cranked axle. One wheel on this axle ran in the furrow and the other on hard ground. A small swivel wheel in front kept the whole steady. A lever on the axle which was operated by a rope leading to the fireman at the rear of the engine engaged the plows or threw them out of action immediately. The plows were also adjustable to run at any depth. They were hinged on the beam, and secured by a brace having a safety pin

of known strength. In case of striking a bowlder or land-fast stone the safety pin broke and the plow turning back on its hinge escaped all injury. The time lost in remedying such a break was not over one minute and the cost not over a couple of cents. During the first year's experience every such accident cost a plow.

The breaking plows were attached loosely to a triangular carriage, and having broad soles did not need the rigid connection necessary for stubble plows. As soon as the engine started each plow took its line of draft and turned its sod, 20 inches wide, and often 30 feet long without a break. One of the main objects of this loose connection was to enable a plow to be immediately detached in order to sharpen it. It required the services of one man to sharpen the plows, and there being extra plows the full number of five were always at work. No better sight could be offered a farmer than to see these fine green waves following in the wake of the steamer.

The first really great achievement of the Williamson Steam Plow was in the testing trials of one sold to Col. Thompson of Minnesota, when with a gang of five 20 inch breaking plows, it actually plowed four acres in an hour of virgin prairie. The power exerted may be estimated from the fact that a 20 inch breaking plow is usually drawn by four yoke of oxen, and the amount plowed is not over an acre per day. Of course the four acres per hour was an extreme amount, but Col. Thompson afterwards reported 30 acres per day of 10 hours as being the regular work of the engine. One of the engines was taken by Messrs. Landreth & Sons, on their celebrated seed farm in Pennsylvania. The peculiarity of their special crops required a continued shifting of their work, and the ability of the engine with its plows to go from one field to another was of great importance. In addition to the plow furnished with the engine, the Messrs. Landreth constructed a very ingenious cultivator for stirring the subsoil without turning it up. It worked admirably, thoroughly breaking up the hard pan and loosening the soil to a depth of 14 inches. It made a heavier draft on the engine than did the gang plow. They also used their engine for drawing manure from their docks on the Deleware to the fields, taking up to 9 tons at once. In other parts of the country they were introduced with every prospect of success. Difficulties which arose were mostly overcome and it was believed that their permanent success was assured. The rubber tires worked to a charm, and so long as the ground was dry enough for horses to plow the steamer would hold its own. The turning at the ends of the field was by practice reduced much below that accomplished by teams in actual competition. But now came a new test–that of plowing loose soil which had been baked to a dry powder by the fierce heat of our summer sun. And here is where an entirely new and fatal objection arose which had never before presented itself. The *dust*, which was stirred up and scattered by the driving wheels combined with that made by the plows, enveloped everything so that the engine moved in a dense cloud. The driver and fireman could not be recognized. The "dust-tight" joints of the engine covers proved of no avail, and instead of ten hours of work being accomplished per day in plowing, but one half were so occupied, whilst the other five were required for cleaning the engine. Even this division of time was not the only loss, for the engines were cutting themselves to pieces and every bearing, however well guarded, was heating and wearing. After fighting the dust bravely for a long time, trying in every way to protect the machinery from its disastrous effect, it became evident that the objection was to a certain extent fatal. The same difficulty would present itself every year in most parts of the country. This, coupled with difficulties inherent in any system of steam plowing, and which will be noticed hereafter, caused the reluctant abandonment of the enterprise. The engines and plows had abundantly accomplished all and more than had been expected of them at the time they were built, but they had also, unfortunately, developed the fact that there were not enough farmers in this country able to purchase such very expensive machinery to create a demand large enough to make their construction a profitable business, even if the dust difficulty and other

objections could by further experiment be overcome. To be sold at reasonable rates the engines would have to be made in series of at least ten at one time, for there was much more work upon them than on locomotives.

It may be asked why confess that the hard work of five years and the expenditure of so many thousands of dollars had resulted in a partial failure? One answer is that many of the objections could not be seen at the start, and indeed required all that time and money to develop them. Another answer is that every engineer or manufacturer, engaged in so important an enterprise as steam plowing owes it to the hundreds of ingenious inventors who may follow him to give the results of his experience, be they successes or failures. In no other way will coming men take up the work where others leave off, but they will go over the same ground, which will lead only to disappointment and loss. No other American ever built ten engines, or had such a large experience. Never did engineers and agriculturalists of such ability assist so heartily to command success, and in no country were the trials conducted with more perseverance and conscientiousness.

Plowing by direct traction not being suitable for all conditions of soil, it may be asked whether the English steam plowing system is adapted to this country. My answer is that it may answer admirably under certain conditions, but that it is impractical for the *average* American Farmer.

A brief description of the English system, the working of which I carefully inspected in England during the last plowing season, must first be given. Among the many different systems all, however, based upon rope traction, which have been before the British public for the last five years, the only two which are now considered practical are the "direct tackle," being a traction engine on each side of the field which move along on the headlands and wind up a wire rope to which the plow is attached, and the single engine "tackle" where the engine generally remains stationary, in one corner of the field, whilst two "traveling anchors" move along the headland and between which the implement works back and forth. The first mentioned requires at least five and often seven hands and four horses, and could not be laid down on a farm in America for less than $12,000 to $15,000 cash. The second is worked with one or two hands less, and would cost about $6,000 to $7,500 when ready for work. It, however, requires a much longer time to set to work and to take up than the double engine system.

The traction engines used with the direct tackle are very large and powerful, weighing from 15 to 20 tons each. They are fitted with winding drums under their locomotive boilers, which are driven by bevil gears from the crank shaft. A clutch throws the road gear into action, and the engine moves just the width of the plows and stops. The winding drum then revolving draws the plow towards it. Meanwhile the engine on the opposite headland moves into position and in turn draws the plow on its return "bout." The plow which is very heavy and cumbersome, consists of two diagonal beams balanced on a pair of wheels. On one beam are the right hand plows, and on the other the left hand plows. It has the advantage of leaving no dead furrows. It has, however, no provision for avoiding a breakage in case of meeting land-fast stones. Two boys, stationed at proper distances from each other, place rope porters or pullies under the running rope to keep it from the ground. These are removed as the plow nears them, and they are placed in position again as soon as the plow has passed. In case of wide or uneven fields more boys with porters are necessary, as the wire rope especially in gritty soil suffers from attrition.

The single engine system consists of one traction engine which can either travel on one headland with a traveling anchor opposite, or what, is still better, in many fields can be placed stationary in one corner of the field. From its fly wheel a belt drives a windlass which winds and unwinds on two drums the wire rope. The latter passes around two traveling anchors which move automatically along the headlands, with the plow working between them.

There are also sets of tackle worked by a portable engine, but these accomplish but little work. An engine which will do a fair amount of work is too

powerful and heavy to be hauled about with horses—it must be self-moving. All the rope tackles waste a great deal of power by friction. The weight of coal expended per acre is exactly the same as that used by the Williamson system, when the engine travels across the field. The reasons why I think the English system is not suited for this country are deduced from actual experience, in connection with my own engines, and many of which will apply to any system yet proposed. They are:

1st. Their excessive cost. Very few farmers in this country can afford to pay out $7,500 to $15,000 in cash for a single implement.

2d. The shortness of the plowing season here would make it possible only to use this expensive machinery about one third of the year.

3d. On account of the important place Indian corn occupies in our crops, for the cultivation of which horses are necessary, the dispensing with horses (which should be one of the advantages of the steam plow) could not be accomplished. To have a stable full of horses standing idle whilst the steam plow was at work would scarcely be economical.

4th. In many of the States, especially in the West, the long dry summers produce a scarcity of water, and often stock must be driven long distances to water. In such districts it would be impossible to procure the 1,000 to 2,000 gallons which would be required daily. The ordinary barn-yard well would be altogether inadequate. (In Minnesota the water for the Williamson plow was carted a distance of over four miles).

5th. Good engineers cannot be hired for short terms of service. In England, where there is always a surplus of such skilled labor, it is possible to engage them at short notice for only the plowing season. Few good men would leave our cities to go far into the country for only three months. The wear and tear on the machinery is very considerable, and competent engineers must be employed who can keep their engines in repair.

5th. Our distances are too great and our season too short to make the cooperative system practicable. Every farmer would want the steamer at the same time. The enormous weight of the English engine would require all the usual bridges to be strengthened, and this would make their removal from one farm to another excessively expensive.

Lastly, plowing by the English system, while it is very thorough, costs as much if not more than by horses. Nothing can compete with oxen, for they can be worked until the season is over, and then fattened and eaten. The double engine system, which gives the most economical results, requires generally seven hands and four horses, (the latter for hauling water), and the implement used is a fine gang plow. The cost of the above force (taking into account the extra pay of engineers) would equal 5 plows, with one man and two horses to each. It is true that the latter 5 plows would not accomplish as much as the former, but the difference would not compensate for the ton of coal, the interest and the wear of engines and wire rope. The report of a committee appointed to examine the depreciation of the wire rope, stated it to be 7 pence sterling (about 15 cents currency) per acre.

The double engine system imported by Mr. Lawrence for his sugar plantation in Louisiana, and said to have cost $20,000, drew a single plow which cut a furrow 3 feet deep. This was certainly very wonderful plowing, and gave a large increase in the crop, but not great enough to make it pay. Another, set on a neighboring plantation, was abandoned as being unprofitable. During the two years when the duty was removed from steam plows to encourage their importation, few if any were imported, although many intelligent farmers had visited England to inquire into their working. At present they must pay a duty of 35 per cent. In Cuba they proved, as in Louisiana, a mechanical success, but they did not reduce the number of Negroes and mules. When used to clear the fields of cane, they set fire to the dry leaves and spread destruction through several plantations. The question of fire is a most serious one in all dry countries.

There are many reasons why no comparison can be made between the use of the steam plow in Great Britain and in America. These differences should be well studied both by inventors and pur-

chasers who may read only of their success in England.

In Great Britain horses and horse feed are much dearer than with us, and the use of oxen is by law forbidden. Coals, engineer's wages, and interest are less than here, and wells a hundred times more abundant. The notoriously wet climate of England makes plowing much more difficult than with us; and every American traveling there is surprised to see three or four immense horses in tandem before a single plow, and accomplishing but about an acre per day. These heavy horses, treading in each others steps in heavy wet clay for many years, eventually pack the soil into a hard pan, through which the roots of the plants cannot penetrate, and to break up this hard pan their peculiar steam cultivator, an implement here, is invaluable.

In England and Scotland the plowing season is longer than with us, and for that reason a neighborhood can club together and buy a steam plow; with us the time for plowing is so short that all would want it at the same time.

The conclusion of all this is, that those who may be ambitious to invent a steam plow have now no excuse for wasting time or money. It used to be said that former attempts in America had not been successful because the engines were too cheaply constructed. "They were built in country machine shops and did not combine all the modern improvements. They were run by men who knew more about agriculture than about engineering, and that, owing to very limited means, no advantage could be taken by those who had failed to follow up their experience by constructing new and improved engines." This argument no longer obtains. Until radical changes are made in railway locomotives, there can be no important improvement on the dozen of Williamson engines which have been worked in as many different states of the Union. Especially must the idea be abandoned that a serviceable engine can be made to weigh only two or three tons. It must be borne in mind that a steam plow should be able to plow at least one acre per hour. One of the largest builders of plowing machinery in England informed me that he could not recommend the use of steam, unless of sufficient power to accomplish that amount of work. This represents the constant work of twenty horses; but it must be remembered that a horse can for a short time exert twice his average pull, and that occasions for this extra work present themselves constantly in plowing, although lasting perhaps for but a few moments at a time. There must be therefore an amount of extra power always at command, so that the opening of a valve wide will at once save a stoppage. Nothing is more demoralizing in steam plowing than continual stoppages. The production of this amount of power requires boilers and engines of suitable size, and the suddeness with which this power is called for requires all connections to be of extraordinary strength. The boiler must always have enough water, and, to ensure this, there can be no liberty taken in cutting down the size of water tanks. These in turn must have coal bunkers of corresponding size. By the time the whole engine has been built in true proportion it will be found to weigh at the *very least* six tons. The engines exhibited by Messrs, Fowler at the Oxford Show weighed 20 tons each.

In the matter of plows it must be remembered that the latest plows, both for stubble and for breaking prairie, as perfected for the Williamson system left nothing to be desired. They were not expensive; were strong, and the work they did was pronounced perfectly satisfactory. No system of rotary plowing has yet been successful, or even if successful, it is not believed that it could supersede the modern plow.

Those who wish to avail themselves of the English system, must carefully consider the following points: The implement used mostly by the British is the steam "Cultivator," an instrument made necessary by their climate, soil and centuries of cultivation. It has taken many years to perfect it for the special crops for which it is used, and for the comparatively even conditions of climate, &c. It will be found that many of these conditions are totally different here, and that what may prove advantageous there, may be quite the reverse with us. The water question is of the most serious importance, much more so than would appear to those who had not experienced it.

The amount of work done must not be estimated from the short "spurts" which are accomplished by trained hands with new engines at agricultural shows, but should be based upon the week's work of a well-managed farm.

All honor be to English engineers who have done so much for British agriculture, and all honor be to those Americans who, finding *all* their conditions the same as those of their British cousins, have the enterprise to order out these expensive improvements, and thus, like true Republicans, use their intelligence and means for the benefit of their fellow men.

For myself, standing at the end of a five year's effort, with enthusiasm tempered by costly experience, with an earnest desire for substantial improvements, but with an equally serious respect for solemn facts, and with a view extending over the whole field, I am constrained to give it as my opinion, that no system of steam plowing yet invented can offer sufficient inducement to make it an object for the average American Farmer to adopt.

MATTER AND MOTION.

By J. CLERK MAXWELL, LL.D., F.R.S.

I.

CHAPTER I.

INTRODUCTION.

NATURE OF PHYSICAL SCIENCE.—Physical science is that department of knowledge which relates to the order of nature, or, in other words, to the regular succession of events.

The name of physical science, however, is often applied in a more or less restricted manner to those branches of science in which the phenomena considered are of the simplest and most abstract kind, excluding the consideration of the more complex phenomena, such as those observed in living beings.

The simplest case of all is that in which an event or phenomenon can be described as a change in the arrangement of certain bodies. Thus the motion of the moon may be described by stating the changes in her position relative to the earth in the order in which they follow one another.

In other cases we may know that some change of arrangement has taken place, but we may not be able to ascertain what that change is.

Thus when water freezes we know that the molecules, or smallest parts of the substance, must be arranged differently in ice and in water. We also know that this arrangement in ice must have a certain kind of symmetry, because the ice is in the form of symmetrical crystals, but we have as yet no precise knowledge of the actual arrangement of the molecules in ice. But whenever we can completely describe the change of arrangement we have a knowledge, perfect so far as it extends, of what has taken place, though we may still have to learn the necessary conditions under which a similar event will always take place.

Hence the first part of physical science ralates to the relative position and motion of bodies.

DEFINITION OF A MATERIAL SYSTEM.—In all scientific procedure we begin by marking out a certain region or subject as the field of our investigations. To this we must confine our attention, leaving the rest of the universe out of account till we have completed the investigation in which we are engaged. In physical science, therefore, the first step is to define clearly the material system which we make the subject of our statements. This system may be of any degree of complexity. It may be a single material particle, a body of finite size, or any number of such bodies, and it may even be extended so as to include the whole material universe.

DEFINITION OF INTERNAL AND EXTERNAL.—All relations or actions between one part of this system and

another are called Internal relations or actions.

Those between the whole or any part of the system, and bodies not included in the system, are called External relations or actions. These we study only so far as they affect the system itself, leaving their effect on external bodies out of consideration. Relations and actions between bodies not included in the system are to be left out of consideration. We cannot investigate them except by making our system include these other bodies.

Definition of Configuration.—When a material system is considered with respect to the relative position of its parts, the assemblage of relative positions is called the configuration of the system.

A knowledge of the configuration of the system at a given instant implies a knowledge of the position of every point of the system with respect to every other point at that instant.

Diagrams.—The configuration of material systems may be represented in models, plans, or diagrams. The model or diagram is supposed to resemble the material system only in form, not necessarily in any other respect.

A plan or a map represents on paper in two dimensions what may really be in three dimensions, and can only be completely represented by a model. We shall use the term Diagram to signify any geometrical figure, whether plane or not, by means of which we study the properties of a material system. Thus, when we speak of the configuration of a system, the image which we form in our minds is that of a diagram, which completely represents the configuration, but which has none of the other properties of the material system. Besides diagrams of configuration we may have diagrams of velocity, of stress, &c., which do not represent the form of the system, but by means of which its relative velocities or its internal forces may be studied.

A Material Particle.—A body so small that, *for the purposes of our investigation*, the distances between its different parts may be neglected, is called a material particle.

Thus in certain astronomical investigations the planets, and even the sun, may be regarded each as a material particle, because the difference of the actions of different parts of these bodies does not come under our notice. But we cannot treat them as material particles when we investigate their rotation. Even an atom, when we consider it as capable of rotation, must be regarded as consisting of many material particles.

The diagram of a material particle is of course a mathematical point, which has no configuration.

Relative Position of two Material Particles.—The diagram of two material particles consists of two points, as, for instance, A and B.

The position of B relative to A is indicated by the direction and length of the straight line $\overline{A\,B}$ drawn *from* A *to* B. If you start from A and travel in the direction indicated by the line $\overline{A\,B}$ and for a distance equal to the length of that line, you will get to B. This direction and distance may be indicated equally well by any other line, such as $\overline{a\,b}$, which is parallel and equal to $\overline{A\,B}$. The position of A with respect to B is indicated by the direction and length of the line $\overline{B\,A}$, drawn *from* B *to* A, or the line $\overline{b\,a}$, equal and parallel to $\overline{B\,A}$.

It is evident that $\overline{B\,A} = -\overline{A\,B}$.

In naming a line by the letters at its extremities, the order of the letters is always that in which the line is to be drawn.

Vectors.—The expression $\overline{A\,B}$, in geometry, is merely the name of a line. Here it indicates the operation by which the line is drawn, that of carrying a tracing point in a certain direction for a certain distance. As indicating an operation, $\overline{A\,B}$ is called a Vector, and the operation is completely defined by the direction and distance of the transference. The starting point, which is called the origin of the vector, may be anywhere.

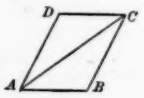
To define a finite straight line we must state its origin as well as its direction and length. All vectors, however, are regarded as equal which are parallel (and drawn towards the same parts) and of the same magnitude.

Any quantity, such, for instance, as a velocity, or a force, which has a definite direction and a definite magnitude may be treated as a vector, and may be indicated in a diagram by a straight line whose direction is parallel to the vector, and whose length represents, according to a determinate scale, the magnitude of the vector.

SYSTEM OF THREE PARTICLES.—Let us next consider a system of three particles.

Its configuration is represented by a diagram of three points, A, B, C.

FIG. 1.



The position of B with respect to A is indicated by the vector $\overline{A\,B}$, and that of C with respect to B by the vector $\overline{B\,C}$.

It is manifest that from these data, when A is known, we can find B and then C, so that the configuration of the three points is completely determined.

The position of C with respect to A is indicated by the vector $\overline{A\,C}$, and by the last remark the value of $\overline{A\,C}$ must be deducible from those of $\overline{A\,B}$ and $\overline{B\,C}$.

The result of the operation $\overline{A\,C}$ is to carry the tracing point from A to C. But the result is the same if the tracing point is carried first from A to B and then from B to C, and this is is the sum of the operations $\overline{A\,B}+\overline{B\,C}$.

ADDITION OF VECTORS.—Hence the rule for the addition of vectors may be stated thus:—From any point as origin draw the successive vectors in series, so that each vector begins at the end of the preceding one. The straight line from the origin to the extremity of the series represents the vector which is the sum of the vectors.

The order of addition is indifferent, for if we write $\overline{B\,C}+\overline{A\,B}$ the operation indicated may be performed by drawing $\overline{A\,D}$ parallel and equal to $\overline{B\,C}$, and then joining $\overline{D\,C}$, which, by Euclid, I. 33, is parallel and equal to $\overline{A\,B}$, so that by these two operations we arrive at the point C in whichever order we perform them.

The same is true for any number of vectors, take them in what order we please.

SUBTRACTION OF ONE VECTOR FROM ANOTHER.—To express the position of C with respect to B in terms of the positions of B and C with respect to A, we observe that we can get from B to C either by passing along the straight line $\overline{B\,C}$ or by passing from B to A and then from A to C. Hence

$$\overline{B\,C}=\overline{B\,A}+\overline{A\,C}.$$

$$=\overline{A\,C}+\overline{B\,A} \text{ since the order of addition is indifferent.}$$

$$=\overline{A\,C}-\overline{A\,B} \text{ since } \overline{A\,B} \text{ is equal and opposite to } \overline{B\,A}.$$

Or, the vector $\overline{B\,C}$, which expresses the position of C with respect to B, is found by subtracting the vector of B from the vector of C, these vectors being drawn to B and C respectively from any common origin A.

ORIGIN OF VECTORS.—The positions of any number of particles belonging to a material system may be defined by means of the vectors drawn to each of these particles from some one point. This point is called the origin of the vectors, or, more briefly, the Origin.

This system of vectors determines the configuration of the whole system; for if we wish to know the position of any point B with respect to any other point A, it may be found from the vectors $\overline{O\,A}$ and $\overline{O\,B}$ by the equation

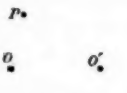
$$\overline{A\,B}=\overline{O\,B}-\overline{O\,A}.$$

We may choose any point whatever for the origin, and there is, for the present, no reason why we should choose one point rather than another. The configuration of the system—that is to say, the position of its parts with respect to each other—remains the same, whatever point be chosen as origin. Many inquiries, however, are simplified by a proper selection of the origin.

RELATIVE POSITION OF TWO SYSTEMS.—If the configurations of two different systems are known, each system having its own origin, and if we then wish to

include both systems in a larger system' having, say, the same origin as the first of the two systems, we must ascertain the position of the origin of the second system with respect to that of the first, and we must be able to draw lines in the second system parallel to those in the first.

FIG. 2.



Then by "System of Three Particles," the position of a point P of the second system, with respect to the first origin, O, is represented by the sum of the vector OP of that point with respect to the second origin, O′ and the vector OO′ of the second origin, O′ with respect to the first, O.

THREE DATA FOR THE COMPARISON OF TWO SYSTEMS.—We have an instance of this formation of a large system out of two or more smaller systems, when two neighboring nations, having each surveyed and mapped its own territory, agree to connect their surveys so as to include both countries in one system. For this purpose three things are necessary.

1st. A comparison of the origin selected by the one country with that selected by the other.

2d. A comparison of the directions of reference used in the two countries.

3d. A comparison of the standards of length used in the two countries.

1. In civilized countries latitude is always reckoned from the equator, but longitude is reckoned from an arbitrary point, as Greenwich or Paris. Therefore, to make the map of Britain fit that of France, we must asertain the difference of longitude between the Observatory of Greenwich and that of Paris.

2. When a survey has been made without astronomical instruments, the directions of reference have sometimes been those given by the magnetic compass. This was, I believe, the case in the original surveys of some of the West India islands. The results of this survey, though giving correctly the local configuration of the island, could not be made to fit properly into a general map of the world till the deviation of the magnet from the true north at the time of the survey was ascertained.

3. To compare the survey of France with that of Britain, the meter, which is the French standard of length, must be compared with the yard, which is the British standard of length.

The yard is defined by Act of Parliament 18 and 19 Vict. c. 72, July 30, 1855, which enacts "that the straight line or distance between the centers of the transverse lines in the two gold plugs in the bronze bar deposited in the office of the Exchequer shall be the genuine standard yard at 62° Fahrenheit, and if lost, it shall be replaced by means of its copies."

The meter derives its authority from a law of the French Republic in 1795. It is defined to be the distance between the ends of a certain rod of platinum made by Borda, the rod being at the temperature of melting ice. It has been found by the measurements of Captain Clarke that the meter is equal to 39.37043 British inches.

ON THE IDEA OF SPACE.—We have now gone through most of the things to be attended to with respect to the configuration of a material system. There remain, however, a few points relating to the metaphysics of the subject, which have a very important bearing on physics.

We have described the method of combining several configurations into one system which includes them all. In this way we add to the small region, which we can explore by stretching our limbs, the more distant regions which we can reach by walking or by being carried. To these we add those of which we learn by the reports of others, and those inaccessible regions whose position we ascertain only by a process of calculation, till at last we recognize that every place has a definite position with respect to every other place, whether the one place is accessible from the other or not.

Thus from measurements made on the earth's surface we deduce the position of the center of the earth relative to known objects, and we calculate the number of cubic miles in the earth's volume quite independently of any hypothesis as to what may exist at the center of the

earth, or in any other place beneath that thin layer of the crust of the earth which alone we can directly explore.

Error of Descartes.—It appears then, that the distance between one thing and another does not depend on any material thing between them, as Descartes seems to assert when he says (Princip. Phil., II. 18) that if that which is in a hollow vessel were taken out of it without anything entering to fill its place, the sides of the vessel, having nothing between them, would be in contact.

This assertion is grounded on the dogma of Descartes, that the extension in length, breadth, and depth which constitute space is the sole essential property of matter. "The nature of matter," he tells us, "or of body considered generally, does not consist in a thing being hard, or heavy, or colored, but only in its being extended in length, breadth, and depth" (Princip., II. 4). By thus confounding the properties of matter with those of space he arrives at the logical conclusion, that if the matter within a vessel could be entirely removed the space within the vessel would no longer exist. In fact he assumes that all space must be always full of matter.

I have referred to this opinion of Descartes in order to show the importance of sound views in elementary dynamics. The primary property of matter was indeed distinctly announced by Descartes in what he calls the "First Law of Nature" (Princip., II. 37): "That every individual thing, so far as in it lies, perseveres in the same state, whether of motion or of rest."

We shall see when we come to Newton's laws of motion that in the words "so far as in it lies," properly understood, is to be found the true primary definition of matter, and the true measure of its quantity. Descartes, however, never attained to a full understanding of his own words (*quantum in se est*), and so fell back on his original confusion of matter with space—space being, according to him, the only form of substance, and all existing things but affections of space. This error runs through every part of Descartes' great work, and it forms one of the ultimate foundations of the system of Spinoza. I shall not attempt to trace it down to more modern times, but I would advise those who study any system of metaphysics to examine carefully that part of it which deals with physical ideas.

We shall find it more conducive to scientific progress to recognise, with Newton, the ideas of time and space as distinct, at least in thought, from that of the material system whose relations these ideas serve to co-ordinate.

On the Idea of Time.—The idea of Time in its most primitive form is probably the recognition of an order of sequence in our states of consciousness. If my memory were perfect, I might be able to refer every event within my own experience to its proper place in a chronological series. But it would be difficult, if not impossible, for me to compare the interval between one pair of events and that between another pair —to ascertain, for instance, whether the time during which I can work without feeling tired is greater or less now than when I first began to study. By our intercourse with other persons, and by our experience of natural processes which go on in a uniform or a rhythmical manner, we come to recognize the possibility of arranging a system of chronology in which all events whatever, whether relating to ourselves or to others, must find their place. Of any two events, say the actual disturbance at the star in Corona Borealis, which caused the luminous effects examined spectroscopically by Mr. Huggins on the 16th May, 1866, and the mental suggestion which first led Professor Adams or M. Leverrier to begin the researches which led to the discovery, by Dr. Galle, on the 23rd September, 1846, of the planet Neptune, the first named must have occured either before or after the other, or else at the same time.

Absolute, true, and mathematical Time is conceived by Newton as flowing at a constant rate, unaffected by the speed or slowness of the motions of material things. It is also called duration. Relative, apparent, and common time is duration as estimated by the motion of bodies, as by days, months, and years. These measures of time may be regarded as provisional, for the progress of astronomy has taught us to measure the

inequality in the lengths of days, months, and years, and thereby to reduce the apparent time to a more uniform scale, called Mean Solar Time.

Absolute Space.—Absolute space is conceived as remaining always similar to itself and immovable. The arrangement of the parts of space can no more be altered than the order of the portions of time. To conceive them to move from their places is to conceive a place to move away from itself.

But as there is nothing to distinguish one portion of time from another except by the different events which occur in them, so there is nothing to distinguish one part of space from another except its relation to the place of material bodies. We cannot describe the time of an event except by reference to some other event, or the place of a body except by reference to some other body. All our knowledge, both of time and place, is essentially relative. When a man has acquired the habit of putting words together, without troubling himself to form the thoughts which ought to correspond to them, it is easy for him to frame an antithesis between this relative knowledge and a so-called absolute knowlege, and to point out our ignorance of the absolute position of a point as an instance of the limitation of our faculties. Any one, however, who will try to imagine the state of a mind conscious of knowing the absolute position of a point will ever after be content with our relative knowledge.

Statement of the General Maxim of Physical Science.—There is a maxim which is often quoted, that "The same causes will always produce the same effects."

To make this maxim intelligible we must define what we mean by the same causes and the same effects, since it is manifest that no event ever happens more than once, so that the causes and effects cannot be the same in *all* respects. What is really meant is that if the causes differ only as regards the absolute time or the absolute place at which the event occurs, so likewise will the effects.

The following statement, which is equivalent to the above maxim, appears to be more definite, more explicitly connected with the ideas of space and time, and more capable of application to particular cases:

"The difference between one event and another does not depend on the mere difference of the times or the places at which they occur, but only on differences in the nature, configuration, or motion of the bodies concerned."

It follows from this, that if an event has occurred at a given time and place it is possible for an event exactly similar to occur at any other time and place.

There is another maxim which must not be confounded with that quoted at the beginning of this article, which asserts "That like causes produce like effects."

This is only true when small variations in the initial circumstances produce only small variations in the final state of the system. In a great many physical phenomena this condition is satisfied; but there are other cases in which a small initial variation may produce a very great change in the final state of the system, as when the displacement of the points causes a railway train to run into another instead of keeping its proper course.

CHAPTER II.

ON MOTION.

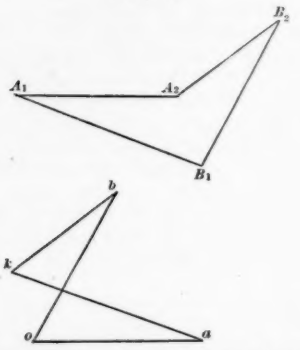
Definition of Displacement.—We have already compared the position of different points of a system at the same instant of time. We have next to compare the position of a point at a given instant with its position at a former instant, called the Epoch.

The vector which indicates the final position of a point with respect to its position at the epoch is called the Displacement of that point. Thus if A_1 is the initial and A_2 the final position of the point A, the line $\overline{A_1 A_2}$ is the displacement of A, and any vector $\overline{o\,a}$ drawn from the origin o parallel and equal to $\overline{A_1 A_2}$ indicates this displacement.

Diagram of Displacement. — If another point of the system is displaced from B_1 to B_2 the vector $\overline{o\,b}$ parallel and equal to $\overline{B_1 B_2}$ indicates the displacement of B.

In like manner the displacement of any number of points may be represented by vectors drawn from the same

FIG. 3.



origin *o*. This system of vectors is called the Diagram of Displacement. It is not necessary to draw actual lines to represent these vectors; it is sufficient to indicate the points *a*, *b*, &c., at the extremities of the vectors. The diagram of displacement may therefore be regarded as consisting of a number of points, *a*, *b*, &c., corresponding with the material particles, A, B, &c., belonging to the system, together with a point *o*, the position of which is arbitrary, and which is the assumed origin of all the vectors.

RELATIVE DISPLACEMENT.—The line $\overline{a\ b}$ in the diagram of displacement represents the displacement of the point B with respect to A.

For if in the diagram of displacement (Fig. 3) we draw $\overline{a\ k}$ parallel and equal to $\overline{B_1\ A_1}$, and in the same direction, and join $\overline{k\ b}$, it is easy to show that $\overline{k\ b}$ is equal and parallel to $\overline{A_2\ B_2}$.

For the vector $\overline{k\ b}$ is the sum of the vectors $\overline{k\ a}$, $\overline{a\ o}$, and $\overline{o\ b}$, and $\overline{A_2\ B_2}$ is the sum of $\overline{A_2\ A_1}$, $\overline{A_1 B_1}$, and $\overline{B_1\ B_2}$. But of these $\overline{k\ a}$ is the same as $\overline{A_1\ B_2}$, $\overline{o\ o}$ is the same as $\overline{A_2\ A_1}$, and $\overline{o\ b}$ is the same as $\overline{B_1\ B_2}$, and by "Addition of Vectors," the order of summation is indifferent, so that the vector $\overline{k\ b}$ is the same, in direction and magnitude, as $\overline{A_2\ B_2}$. Now $\overline{k\ a}$, or $\overline{A_1\ B_1}$ represents the original position of B with respect to A, and $\overline{k\ b}$, or $\overline{A_2\ B_2}$ represents the final position of B with respect to A. Hence $\overline{a\ b}$ represents the displacement of B with respect to A, which was to be proved.

In "Definition of Displacement," we purposely omitted to say whether the origin to which the original configuration was referred, and that to which the final configuration is referred, are absolutely the same point, or whether, during the displacement of the system, the origin also is displaced.

We may now, for the sake of argument, suppose that the origin is absolutely fixed, and that the displacements represented by $\overline{o\ a}$, $\overline{o\ b}$, &c., are the absolute displacements. To pass from this case to that in which the origin is displaced we have only to take A, one of the movable points, as origin. The absolute displacement of A being represented by $\overline{o\ a}$, the displacement of B with respect to A is represented, as we have seen, by $\overline{a\ b}$, and so on for any other points of the system.

The arrangement of the points *a*, *b*, &c., in the diagram of displacement is therefore the same, whether we reckon the displacements with respect to a fixed point or a displaced point; the only difference is that we adopt a different origin of vectors in the diagram of displacements, the rule being that whatever point we take, whether fixed or moving, for the origin of the diagram of configuration, we take the corresponding point as origin in the diagram of displacement. If we wish to indicate the fact that we are entirely ignorant of the absolute displacement in space of any point of the system we may do so by constructing the diagram of displacements as a mere system of points, without indicating in any way which of them we take as the origin.

This diagram of displacements (without an origin) will then represent neither more nor less than all we can ever know about the displacement of the system. It consists simply of a number of points, *a*, *b*, *c*, &c., corresponding to the points A, B, C, of the material system, and a vector, as $\overline{a\ b}$ represents the displacement of B with respect to A.

UNIFORM* DISPLACEMENT.—When the

* When the simultaneous values of a quantity for different bodies or places are equal, the quantity is said to be *uniformly* distributed in space.

displacements of all points of a material system with respect to an external point are the same in direction and magnitude, the diagram of displacement is reduced to two points—one corresponding to the external point, and the other to each and every point of the displaced system. In this case the points of the system are not displaced with respect to one another, but only with respect to the external point.

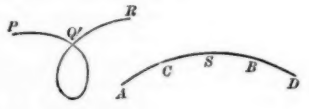
This is the kind of displacement which occurs when a body of invariable form moves parallel to itself. It may be called uniform displacement.

On Motion.—When the change of configuration of a system is considered with respect only to its state at the beginning and the end of the process of change, and without reference to the time during which it takes place, it is called the displacement of the system.

When we turn our attention to the process of change itself, as taking place during a certain time and in a continuous manner, the change of configuration is ascribed to the motion of the system.

On the Continuity of Motion.—When a material particle is displaced so as to pass from one position to another, it can only do so by traveling along some course or path from the one position to the other.

Fig. 4.



At any instant during the motion the particle will be found at some one point of the path, and if we select any point of the path, the particle will pass that point once at least* during its motion.

This is what is meant by saying that the particle described a continuous path.

The motion of a material particle which has continuous existence in time and space is the type and exemplar of every form of continuity.

* If the path cuts itself so as to form a loop, as P, Q, R, (fig. 4), the particle will pass the point of intersection, Q, twice, and if the particle returns on its own path, as in the path A, B, C, D, it may pass the same point, S, three or more times.

On Constant* Velocity.—If the motion of a particle is such that in equal intervals of time, however short, the displacements of the particle are equal and in the same direction, the particle is said to move with constant velocity.

It is manifest that in this case the path of the body will be a straight line, and the length of any part of the path will be proportional to the time of describing it.

The rate or speed of the motion is called the velocity of the particle, and its magnitude is expressed by saying that it is such a distance in such a time, as, for instance, ten miles an hour, or one meter per second. In general we select a unit of time, such as a second and measure velocity by the distance described in unit of time.

If one meter be described in a second and if the velocity be constant, a thousandth or a millionth of a meter will be described in a thousandth or a millionth of a second. Hence, if we can observe or calculate the displacement during any interval of time, however short, we may deduce the distance which would be described in a longer time with the same velocity. This result, which enables us to state the velocity during the short interval of time, does not depend on the body's actually continuing to move at the same rate during the longer time. Thus we may know that a body is moving at the rate of ten miles an hour, though its motion at this rate may last for only the hundredth of a second.

On the Measurement of Velocity when Variable.—When the velocity of a particle is not constant, its value at any given instant is measured by the distance which would be described in unit of time by a body having the same velocity as that which the particle has at that instant.

Thus when we say that at a given instant, say one second after a body has begun to fall, its velocity is 980′ centimeters per second, we mean that if the velocity of a particle were constant and equal to that of the falling body at the given instant, it would describe 980 centimeters in a second.

It is specially important to understand

* When the successive values of a quantity for successive instances of time are eqnal, the quantity is said to be *constant*.

what is meant by the velocity or rate of motion of a body, because the ideas which are suggested to our minds by considering the motion of a particle are those which Newton made use of in his method of Fluxions,* and they lie at the foundation of the great extension of exact science which has taken place in modern times.

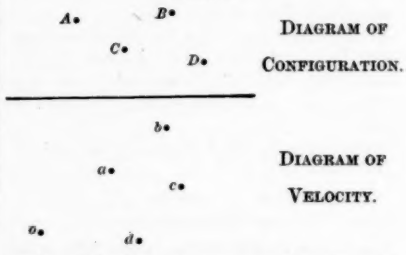
DIAGRAM OF VELOCITIES.—If the velocity of each of the bodies in the system is constant, and if we compare the configurations of the system at an interval of a unit of time, then the displacements, being those produced in unit of time in bodies moving with constant velocities, will represent those velocities according to the method of measurement described "On Constant Velocity."

If the velocities do not actually continue constant for a unit of time, then we must imagine another system consisting of the same number of bodies, and in which the velocities are the same as those of the corresponding bodies of the system at the given instant, but remain constant for a unit of time. The displacements of this system represent the velocities of the actual system at the given instant.

Another mode of obtaining the diagram of velocities of a system at a given instant is to take a small interval of time, say the nth part of the unit of time, so that the middle of this interval corresponds to the given instant. Take the diagram of displacements corresponding to this interval and magnify all its dimensions n times. The result will be a diagram of the *mean* velocities of the system during the interval. If we now suppose the number n to increase without limit the interval will diminish without limit, and the mean velocities will approximate without limit to the actual velocities at the given instant. Finally, when n becomes infinite the diagram will represent accurately the velocities at the given instant.

PROPERTIES OF THE DIAGRAM OF VELOCITIES. (Fig. 5).—The diagram of velocities for a system consisting of a number of material particles consists of a number of points, each corresponding to one of the particles.

FIG. 5.



The velocity of any particle B with respect to any other, A, is represented in direction and magnitude by the line $\overline{a\,b}$ in the diagram of velocities, drawn from the point a, corresponding to A, to the point b, corresponding to B.

We may in this way find, by means of the diagram, the relative velocity of any two particles. The diagram tells us nothing about the absolute velocity of any point; it expresses exactly what we can know about the motion and no more. If we choose to imagine that $\overline{oa}$ represents the absolute velocity of A, then the absolute velocity of any other particle, B, will be represented by the vector $\overline{o\,b}$, drawn from o as origin, to the point b, which corresponds to B.

But as it is impossible to define the position of a body except with respect to the position of some point of reference, so it is impossible to define the velocity of a body, except with respect to the velocity of the point of reference. The phrase absolute velocity has as little meaning as absolute position. It is better, therefore, not to distinguish any point in the diagram of velocity as the origin, but to regard the diagram as expressing the relations of all the velocities without defining the absolute value of any one of them.

MEANING OF THE PHRASE "AT REST."—It is true that when we say that a body is at rest we use a form of words which appears to assert something about that body considered in itself, and we might imagine that the velocity of another body, if reckoned with respect to a body at rest, would be its true and only absolute velocity. But the phrase

* According to the method of Fluxions, when the value of one quantity depends on that of another, the rate of variation of the first quantity with respect to the second may be expressed as a velocity, by imagining the first quantity to represent the displacement of a particle, while the second flows uniformly with the time.

"at rest" means in ordinary language "having no velocity with respect to that on which the body stands," as, for instance, the surface of the earth or the deck of a ship. It cannot be made to mean more than this.

It is therefore unscientific to distinguish between rest and motion, as between two different states of a body in itself, since it is impossible to speak of a body being at rest or in motion except with reference, expressed or implied, to some other body.

On Change of Velocity.—As we have compared the velocities of different bodies at the same time, so we may compare the relative velocity of one body with respect to another at different times.

If a_1, b_1, c_1, be the diagram of the velocities of the system of bodies, A, B, C, in

Fig. 6.

its original state, and if a_2, b_2, c_2, be the diagram of velocities in the final state of the system, then if we take any point ω as origin and draw $\overline{\omega\, a}$ equal and parallel to $\overline{a_1\, a_2}$, $\overline{\omega\, \beta}$ equal and parallel to $\overline{b_1\, b_2}$, $\overline{\omega\, \gamma}$ equal and parallel to $\overline{c_1\, c_2}$, and so on, we shall form a diagram of points a, β, γ, &c., such that any line $\overline{a\, \beta}$ in this diagram represents in direction and magnitude the change of the velocity of B with respect to A. This diagram may be called the diagram of Total Accelerations.

On Acceleration.—The word Acceleration is here used to denote any change in the velocity, whether that change be an increase, a diminution, or a change of direction. Hence, instead of distinguishing, as in ordinary language, between the acceleration, the retardation, and the deflection of the motion of a body, we say that the acceleration may be in the direction of motion, in the contrary direction, or transverse to that direction.

As the displacement of a system is defined to be the change of the configuration of the system, so the Total Acceleration of the system is defined to be the change of the velocities of the system. The process of constructing the diagram of total accelerations, by a comparison of the initial and final diagrams of velocities, is the same as that by which the diagram of displacements was constructed by a comparison of the initial and final diagrams of configuration.

On the Rate of Acceleration.—We have hitherto been considering the total acceleration which takes place during a certain interval of time. If the rate of acceleration is constant, it is measured by the total acceleration in a unit of time. If the rate of acceleration is variable, its value at a given instant is measured by the total acceleration in unit of time of a point whose acceleration is constant and equal to that of the particle at the given instant.

It appears from this definition that the method of deducing the rate of acceleration from a knowledge of the total acceleration in any given time is precisely analogous to that by which the velocity at any instant is deduced from a knowledge of the displacement in any given time.

The diagram of total accelerations constructed for an interval of the nth part of the unit of time, and then magnified n times, is a diagram of the mean rates of acceleration during that interval, and by taking the interval smaller and smaller, we ultimately arrive at the true rate of acceleration at the middle of that interval.

As rates of acceleration have to be considered in physical science much more frequently than total accelerations, the word acceleration has come to be employed in the sense in which we have hitherto used the phrase—rate of acceleration.

In future, therefore, when we use the word acceleration without qualification, we mean what we have here described as the rate of acceleration.

DIAGRAM OF ACCELERATIONS.—The diagram of accelerations is a system of points, each of which corresponds to one of the bodies of the material system, and is such that any line $\overline{\alpha\beta}$ in the diagram represents the rate of acceleration of the body B with respect to the body A.

It may be well to observe here that in the diagram of configuration we use the capital letters, A, B, C, &c., to indicate the relative position of the bodies of the system; in the diagram of velocities we use the small letters, *a*, *b*, *c*, to indicate the relative velocities of these bodies; and in the diagram of accelerations we use the Greek letters, α, β, γ, to indicate their relative accelerations.

ACCELERATION A RELATIVE TERM.—Acceleration, like position and velocity, is a relative term and cannot be interpreted absolutely.

If every particle of the material universe within the reach of our means of observation were at a given instant to have its velocity altered by compounding therewith a new velocity, the same in magnitude and direction for every such particle, all the relative motions of bodies within the system would go on in a perfectly continuous manner, and neither astronomers nor physicists, though using their instruments all the while, would be able to find out that anything had happened.

It is only if the change of motion occurs in a different manner in the different bodies of the system that any event capable of being observed takes place.

CHAPTER III.

ON FORCE.

KINEMATICS AND KINETICS.—We have hitherto been considering the motion of a system in its purely geometrical aspect. We have shown how to study and describe the motion of such a system, howevery arbitrary, without taking into account any of the conditions of motion which arise from the mutual action between the bodies.

The theory of motion treated in this way is called Kinematics. When the mutual action between bodies is taken into account, the science of motion is called Kinetics, and when special attention is paid to force as the cause of motion, it is called Dynamics.

MUTUAL ACTION BETWEEN TWO BODIES —STRESS.—The mutual action between two portions of matter receives different names according to the aspect under which it is studied, and this aspect depends on the extent of the material system which forms the subject of our attention.

If we take into account the whole phenomenon of the action between the two portions of matter, we call it Stress. This stress, according to the mode in which it acts, may be described as Attraction, Repulsion, Tension, Pressure, Shearing stress, Torsion, &c.

EXTERNAL FORCE.—But if, as in "Definition of a Material System," we confine our attention to one of the portions of matter, we see, as it were, only one side of the transaction—namely, that which affects the portion of matter under our consideration—and we call this aspect of the phenomenon, with reference to its effect, an External Force acting on that portion of matter, and with reference to its cause we call the Action of the other portion of matter. The opposite aspect of the stress is called the Reaction on the other portion of matter.

DIFFERENT ASPECTS OF THE SAME PHENOMENON.—In commercial affairs the same transaction between two parties is called Buying when we consider one party, Selling when we consider the other, and Trade when we take both parties into consideration.

The accountant who examines the records of the transaction finds that the two parties have entered it on opposite sides of their respective ledgers, and in comparing the books he must in every case bear in mind in whose interest each book is made up.

For similar reasons in dynamical investigations we must always remember which of the two bodies we are dealing with, so that we may state the forces in the interest of that body, and not set down any of the forces on the wrong side of the account.

NEWTON'S LAWS OF MOTION.—External or "impressed" force considered with reference to its effect—namely, the alteration of the motions of bodies—is completely defined and described in Newton's three laws of motion.

The first law tells us under what conditions there is no external force.

The second shows us how to measure the force when it exists.

The third compares the two aspects of the action between two bodies, as it affects the one body or the other.

THE FIRST LAW OF MOTION.—LAW I. *Every body perseveres in its state of rest or of moving uniformly in a straight line, except in so far as it is made to change that state by external forces.*

The experimental argument for the truth of this law is, that in every case in which we find an alteration of the state of motion of a body, we can trace this alteration to some action between that body and another, that is to say, to an external force. The existence of this action is indicated by its effects on the other body when the motion of that body can be observed. Thus the motion of a cannon ball is retarded, but this arises from an action between the projectile and the air which surrounds it, whereby the ball experiences a force in the direction opposite to its relative motion, while the air, pushed forward by an equal force, is itself set in motion, and constitutes what is called the *wind* of the cannon ball.

But our conviction of the truth of this law may be greatly strengthened by considering what is involved in a denial of it. Given a body in motion. At a given instant let it be left to itself and not acted on by any force. What will happen? According to Newton's law it will persevere in moving uniformly in a straight line, that is, its velocity will remain constant both in direction and magnitude.

If the velocity does not remain constant let us suppose it to vary. The change of velocity, as we saw "On Change of Velocity," must have a definite direction and magnitude. By the "Statement of the General Maxim of Physical Science," this variation must be the same whatever be the time or place of the experiment. The direction of the change of motion must therefore be determined either by the direction of the motion itself, or by some direction fixed in the body.

Let us, in the first place, suppose the law to be that the velocity diminishes at a certain rate, which for the sake of the argument we may suppose so slow that by no experiments on moving bodies could we have detected the diminution of velocity in hundreds of years.

The velocity referred to in this hypothetical law can only be the velocity referred to a point absolutely at rest. For if it is a relative velocity its direction as well as its magnitude depends on the velocity of the point of reference.

If, when referred to a certain point, the body appears to be moving northward with diminishing velocity, we have only to refer it to another point moving northward with a uniform velocity greater than that of the body, and it will apper to be moving southward with increasing velocity.

Hence the hypothetical law is without meaning, unless we admit the possibility of defining absolute rest and absolute velocity.

Even if we admit this as a possibility, the hypothetical law, if found to be true, might be interpreted, not as a contradiction of Newton's law, but as evidence of the resisting action of some medium in space.

To take another case. Suppose the law to be that a body, not acted on by any force, ceases at once to move. This is not only contradicted by experience, but it leads to a definition of absolute rest as the state which a body assumes as soon as it is freed from the action of external forces.

It may thus be shown that the denial of Newton's law is in contradiction to the only system of consistent doctrine about space and time which the human mind has been able to form.

ON THE EQUILIBRIUM OF FORCES.—If a body moves with constant velocity in a straight line, the external forces, if any, which act on it, balance each other, or are in equilibrium.

Thus if a carriage in a railway train moves with constant velocity in a straight line, the external forces which act on it —such as the traction of the carriage in front of it pulling it forwards, the drag of that behind it, the friction of the rails, the resistance of the air acting backwards, the weight of the carriage acting downwards, and the pressure of the rails acting upwards—must exactly balance each other.

Bodies at rest with respect to the surface of the earth are really in motion, and their motion is not constant nor in a straight line. Hence the forces which act on them are not exactly balanced. The apparent weight of bodies is estimated by the upward force required to keep them at rest relatively to the earth. The apparent weight is therefore rather less than the attraction of the earth, and makes a smaller angle with the axis of the earth, so that the combined effect of the supporting force and the earth's attraction is a force perpendicular to the earth's axis just sufficient to cause the body to keep to the circular path which it must describe if resting on the earth.

DEFINITION OF EQUAL TIMES.—The first law of motion, by stating under what circumstances the velocity of a moving body remains constant, supplies us with a method of defining equal intervals of time. Let the material system consist of two bodies which do not act on one another, and which are not acted on by any body external to the system. If one of these bodies is in motion with respect to the other, the relative velocity will, by the first law of motion, be constant and in a straight line.

Hence intervals of time are equal when the relative displacements during those intervals are equal.

This might at first sight appear to be nothing more than a definition of what we mean by equal intervals of time, an expression which we have not hitherto defined at all.

But if we suppose another moving system of two bodies to exist, each of which is not acted upon by any body whatever, this second system will give us an independent method of comparing intervals of time.

The statement that equal intervals of time are those during which equal displacements occur in any such system, is therefore equivalent to the assertion that the comparison of intervals of time leads to the same result, whether we use the first system of two bodies or the second system as our time-piece.

We thus see the theoretical possibility of comparing intervals of time however distant, though it is hardly necessary to remark that the method cannot be put in practice in the neighborhood of the earth, or any other large mass of gravitating matter.

THE SECOND LAW OF MOTION.—Law II.—*Change of motion is proportional to the impressed force, and takes place in the direction in which the force is impressed.*

By motion Newton means what in modern scientific language is called momentum, in which the quantity of matter moved is taken into account as well as the rate at which it travels.

By impressed force he means what is now called Impulse, in which the time during which the force acts is taken into account as well as the intensity of the force.

DEFINITION OF EQUAL MASSES AND OF EQUAL FORCES.—An exposition of the law therefore involves a definition of equal quantities of matter and of equal forces.

We shall assume that it is possible to cause the force with which one body acts on another to be of the same intensity on different occasions.

If we admit the permanency of the properties of bodies this can be done. We know that a thread of caoutchouc when stretched beyond a certain length exerts a tension which increases the more the thread is elongated. On account of this property the thread is said to be elastic. When the same thread is drawn out to the same length it will, if its properties remain constant, exert the same tension. Now let one end of the thread be fastened to a body, M, not acted on by any other force than the tension of the thread, and let the other end be held in the hand and pulled in a constant direction with a force just sufficient to elongate the thread to a given length; the force acting on the body will then be of a given intensity, F. The body will acquire velocity, and at the end of a unit of time this velocity will have a certain value, V.

If the same string be fastened to another body, N, and pulled as in the former case, so that the elongation is the same as before, the force acting on the body will be the same, and if the velocity communicated to N in a unit of time is also the same, namely, V, then we say of the two bodies M and N that they consist of equal quantities of mat-

ter, or, in modern language, they are equal in mass. In this way, by the use of an elastic string, we might adjust the masses of a number of bodies so as to be each equal to a standard unit of mass, such as a pound avoirdupois, which is the standard of mass in Britain.

Measurement of Mass.—The scientific value of the dynamical method of comparing quantities of matter is best seen by comparing it with other methods in actual use.

As long as we have to do with bodies of exactly the same kind, there is no difficulty in understanding how the quantity of matter is to be measured. If equal quantities of the substance produce equal effects of any kind, we may employ these effects as measures of the quantity of the substance.

For instance, if we are dealing with sulphuric acid of uniform strength, we may estimate the quantity of a given portion of it in several different ways. We may weigh it, we may pour it into a graduated vessel, and so measure its volume, or we may ascertain how much of a standard solution of potash it will neutralize.

We might use the same methods to estimate a quantity of nitric acid if we were dealing only with nitric acid; but if we wished to compare a quantity of nitric acid with a quantity of sulphuric acid we should obtain different results by weighing, by measuring, and by testing with an alkaline solution.

Of these three methods, that of weighing depends on the attraction between the acid and the earth, that of measuring depends on the volume which the acid occupies, and that of titration depends on its power of combining with potash.

In abstract dynamics, however, matter is considered under no other aspect than as that which can have its motion changed by the application of force. Hence any two bodies are of equal mass if equal forces applied to these bodies produce, in equal times, equal changes of velocity. This is the only definition of equal masses which can be admitted in dynamics, and it is applicable to all material bodies, whatever they may be made of.

It is an observed fact that bodies of equal mass, placed in the same position relative to the earth, are attracted equally towards the earth, whatever they are made of; but this is not a doctrine of abstract dynamics, founded on axiomatic principles, but a fact discovered by observation, and verified by the careful experiments of Newton,* on the times of oscillation of hollow wooden balls suspended by strings of the same length, and containing gold, silver, lead, glass, sand, common salt, wood, water, and wheat.

The fact, however, that in the same geographical position the weights of equal masses are equal, is so well established, that no other mode of comparing masses than that of comparing their weights is ever made use of, either in commerce or in science, except in researches undertaken for the special purpose of determining, in absolute measure, the weight of unit of mass at different parts of the earth's surface. The method employed in these researches is essentially the same as that of Newton, namely, by measuring the length of a pendulum which swings seconds.

The unit of mass in this country is defined by the Act of Parliament (18 & 19 Vict. c. 72, July 30, 1855) to be a piece of platinum marked "P. S., 1844, 1 lb." deposited in the office of the Exchequer, which "shall be and be denominated the Imperial Standard Pound Avoirdupois." One seven-thousandth part of this pound is a grain. The French Standard of mass is the "Kilogramme des Archives," made of platinum by Borda. Professor Miller finds the kilogramme equal to 15432.34874 grains.

Numerical Measurement of Force.—The unit of force is that force which, acting on the unit of mass for the unit of time, generates unit of velocity.

Thus the weight of a gramme—that is to say, the force which causes it to fall—may be asserted by letting it fall freely. At the end of one second its velocity will be about 981 centimeters per second if the experiment be in Britain. Hence the weight of a gramme is represented by the number 981, if the centimeter, the gramme, and the second are taken as the fundamental units.

It is sometimes convenient to compare forces with the weight of a body, and to speak of a force of so many pounds

* "Principia," III., Prop. 6.

weight or grammes weight. This is called Gravitation measure. We must remember, however, that though a pound or a gramme is the same all over the world, the weight of a pound or a gramme is greater in high latitudes than near the equator, and therefore a measurement of force in gravitation measure is of no scientific value unless it is stated in what part of the world the measurement was made.

If, as in Britain, the units of length, mass, and time are one foot, one pound, and one second, the unit of force is that which, in one second, would communicate to one pound a velocity of one foot per second. This unit of force is called a *Poundal.*

In the French metric system the units are one centimeter, one gramme, and one second. The force which in one second would communicate to one gramme a velocity of one centimeter per second is called a *Dyne.*

Since the foot is 30.4797 centimeters and the pound is 453.59 grammes, the poundal is 13825.38 dynes.

Simultaneous Action of Forces on a Body.—Now let a unit of force act for unit of time upon unit of mass. The velocity of the mass will be changed, and the total acceleration will be unity in the direction of the force.

The magnitude and direction of this total acceleration will be the same whether the body is originally at rest or in motion. For the expression "at rest" has no scientific meaning, and the expression "in motion," if it refers to relative motion, may mean anything, and if it refers to absolute motion can only refer to some medium fixed in space. To discover the existence of a medium, and to determine our velocity with respect to it by observation on the motion of bodies, is a legitimate scientific inquiry, but supposing all this done we should have discovered, not an error in the laws of motion, but a new fact in science.

Hence the effect of a given force on a body does not depend on the motion of that body.

Neither is it affected by the simultaneous action of other forces on the body. For the effect of these forces on the body is only to produce motion in the body, and this does not affect the acceleration produced by the first force.

Hence we arrive at the following form of the law. *When any number of forces act on a body, the acceleration due to each force is the same in direction and magnitude as if the others had not been in action.*

When a force, constant in direction and magnitude, acts on a body, the total acceleration is proportional to the interval of time during which the force acts.

For if the force produces a certain total acceleration in a given interval of time, it will produce an equal total acceleration in the next, because the effect of the force does not depend upon the velocity which the body has when the force acts on it. Hence in every equal interval of time there will be an equal change of the velocity, and the total change of velocity from the beginning of the motion will be proportional to the time of action of the force.

The total acceleration in a given time is proportional to the force.

For if several equal forces act in the same direction on the same body in the same direction, each produces its effect independently of the others. Hence the total acceleration is proportional to the number of the equal forces.

On Impulse.—The total effect of a force in communicating velocity to a body is therefore proportional to the force and to the time during which it acts conjointly.

The product of the time of action of a force into its intensity if it is constant, or its mean intensity if it is variable, is called the *Impulse* of the force.

There are certain cases in which a force acts for so short a time that it is difficult to estimate either its intensity or the time during which it acts. But it is comparatively easy to measure the effect of the force in altering the motion of the body on which it acts, which, as we have seen, depends on the impulse.

The word impulse was originally used to denote the effect of a force of short duration, such as that of a hammer striking a nail. There is no essential difference, however, between this case and any other case of the action of force. We shall therefore use the word impulse as above defined, without restricting it

to cases in which the action is of an exceptionally transient character.

Relation between Force and Mass.—If a force acts on a unit of mass for a certain interval of time, the impulse, as we have seen, is measured by the velocity generated.

If a number of equal forces act in the same direction, each on a unit of mass, the different masses will all move in the same manner, and may be joined together into one body without altering the phenomenon. The velocity of the whole body is equal to that produced by one of the forces acting on a unit of mass.

Hence the force required to produce a given change of velocity in a given time is proportional to the number of units of mass of which the body consists.

On Momentum.—The numerical value of the Momentum of a body is the product of the number of units of mass in the body into the number of units of velocity with which it is moving.

The momentum of any body is thus measured in terms of the momentum of unit of mass moving with unit of velocity, which is taken as the unit of momentum.

The direction of the momentum is the same as that of the velocity, and as the velocity can only be estimated with respect to some point of reference, so the particular value of the momentum depends on the point of reference which we assume. The momentum of the moon, for example, will be very different according as we take the earth or the sun for the point of reference.

Statement of the Second Law of Motion in Terms of Impulse and Momentum.—*The change of momentum of a body is numerically equal to the impulse which produces it, and is in the same direction.*

Addition of Forces.—If any number of forces act simultaneously on a body, each force produces an acceleration proportional to its own magnitude ("Measurement of Mass"). Hence if in the diagram of accelerations (See "Diagram of Accelerations") we draw from any origin a line representing in direction and magnitude the acceleration due to one of the forces, and from the end of this line another representing the acceleration due to another force, and so on, drawing lines for each of the forces taken in any order, then the line drawn from the origin to the extremity of the last of the lines will represent the acceleration due to the combined action of all the forces.

Since in this diagram lines which represent the accelerations are in the same proportion as the forces to which these accelerations are due, we may consider the lines as representing these forces themselves. The diagram, thus understood, may be called a Diagram of Forces, and the line from the origin to the extremity of the series represents the Resultant Force.

An important case is that in which the set of lines representing the forces terminate at the origin so as to form a closed figure. In this case there is no resultant force, and no acceleration. The effects of the forces are exactly balanced, and the case is one of equilibrium. The discussion of cases of equilibrium forms the subject of the science of Statics.

It is manifest that since the system of forces is exactly balanced, and is equivalent to no force at all, the forces will also be balanced if they act in the same way on any other material system, whatever be the mass of that system. This is the reason why the consideration of mass does not enter into statical investigations.

The Third Law of Motion.—Law III.—*Reaction is always equal and opposite to action, that is to say, the actions of two bodies upon each other are always equal and in opposite directions.*

When the bodies between which the action takes place are not acted on by any other force, the changes in their respective momenta produced by the action are equal and in opposite directions.

The changes in the velocities of the two bodies are also in opposite directions, but not equal, except in the case of equal masses. In other cases the changes of velocity are in the inverse ratio of the masses.

Action and Reaction are the Partial Aspects of a Stress.—We have already ("Mutual Action—Stress," etc.) used the word stress to denote the mutual action between two portions of matter.

This word was borrowed from common language, and invested with a precise scientific meaning by the late Professor Rankine, to whom we are indebted for several other valuable scientific terms.

As soon as we have formed for ourselves the idea of a stress, such as the Tension of a rope or the Pressure between two bodies, and have recognized its double aspect as it affects the two portions of matter between which it acts, the third law of motion is seen to be equivalent to the statement that all force is of the nature of stress, that stress exists only between two portions of matter, and that its effects on these portions of matter (measured by the momentum generated in a given time) are equal and opposite.

The stress is measured numerically by the force exerted on either of the two portions of matter. It is distinguished as a tension when the force acting on either portion is towards the other, and as a pressure when the force acting on either portion is away from the other.

When the force is inclined to the surface which separates the two portions of matter the stress cannot be distinguished by any term in ordinary language, but must be defined by technical mathematical terms.

When a tension is exerted between two bodies by the medium of a string, the stress, properly speaking, is between any two parts into which the string may be supposed to be divided by an imaginary section or transverse interface. If, however, we neglect the weight of the string, each portion of the string is in equilibrium under the action of the tensions at its extremities, so that the tensions at any two transverse interfaces of the string must be the same. For this reason we often speak of the tension of the string as a whole, without specifying any particular section of it, and also the tension between the two bodies, without considering the nature of the string through which the tension is exerted.

Attraction and Repulsion.—There are other cases in which two bodies at a distance appear mutually to act on each other, though we are not able to detect any intermediate body, like the string in the former example, through which the action takes place. For instance, two magnets or two electrified bodies appear to act on each other when placed at considerable distances apart, and the motions of the heavenly bodies are observed to be affected in a manner which depends on their relative position.

This mutual action between distant bodies is called attraction when it tends to bring them nearer, and repulsion when it tends to separate them.

In all cases, however, the action and reaction between the bodies are equal and opposite.

The Third Law True of Action at a Distance.—The fact that a magnet draws iron towards it was noticed by the ancients, but no attention was paid to the force with which the iron attracts the magnet. Newton, however, by placing the magnet in one vessel and the iron in another, and floating both vessels in water so as to touch each other, showed experimentally that as neither vessel was able to propel the other along with itself through the water, the attraction of the iron on the magnet must be equal and opposite to that of the magnet on the iron, both being equal to the pressure between the two vessels.

Having given this experimental illustration Newton goes on to point out the consequence of denying the truth of this law. For instance, if the attraction of any part of the earth, say a mountain, upon the remainder of the earth were greater or less than that of the remainder of the earth upon the mountain, there would be a residual force, acting upon the system of the earth and the mountain as a whole, which would cause it to move off, with an ever-increasing velocity, through infinite space.

Newton's Proof not Experimental.—This is contrary to the first law of motion, which asserts that a body does not change its state of motion unless acted on by *external* force. It cannot be affirmed to be contrary to experience, for the effect of an inequality between the attraction of the earth on the mountain and the mountain on the earth would be the same as that of a force equal to the difference of these attractions acting in the direction of the line joining the center of the earth with the mountain.

If the mountain were at the equator the earth would be made to rotate about

an axis parallel to the axis about which it would otherwise rotate, but not passing exactly through the center of the earth's mass.

If the mountain were at one of the poles, the constant force parallel to the earth's axis would cause the orbit of the earth about the sun to be slightly shifted to the north or south of a plane passing through the center of the sun's mass.

If the mountain were at any other part of the earth's surface its effect would be partly of the one kind and partly of the other.

Neither of these effects, unless they were very large, could be detected by direct astronomical observations, and the indirect method of detecting small forces, by their effect in slowly altering the elements of a planet's orbit, presupposes that the law of gravitation is known to be true. To prove the laws of motion by the law of gravitation would be an inversion of scientific order. We might as well prove the law of addition of numbers by the differential calculus.

We cannot, therefore, regard Newton's statement as an appeal to experience and observation, but rather as a deduction of the third law of motion from the first.

CHAPTER IV.

ON THE PROPERTIES OF THE CENTER OF MASS OF A MATERIAL SYSTEM.

Definition of a Mass-Vector.—We have seen that a vector represents the operation of carrying a tracing point from a given origin to a given point.

Let us define a mass-vector as the operation of carrying a given mass from the origin to the given point. The direction of the mass-vector is the same as that of the vector of the mass, but its magnitude is the product of the mass into the vector of the mass.

Thus if $\overline{OA}$ is the vector of the mass A, the mass-vector is $\overline{OA}.A$.

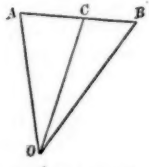
Center of Mass of Two Particles.—If A and B are two masses, and if a point C be taken in the straight line $\overline{AB}$, so that $\overline{BC}$ is to $\overline{CA}$ as A to B, then the mass-vector of a mass A + B placed at C is equal to the sum of the mass-vectors of A and B.

For $\overline{OA}.A+\overline{OB}.B=(\overline{OC}+\overline{CA})A+(\overline{OC}+\overline{CB})B.$

$=\overline{OC}(A+B)+\overline{CA}.A+\overline{CB}.B.$

Now the mass-vectors $\overline{CA}.A$ and $\overline{CB}.B$ are equal and opposite, and so destroy each other, so that $\overline{OA}.A+\overline{OB}.B=\overline{OC}(A+B)$

Fig. 7.



or, C is a point such that if the masses of A and B were concentrated at C, their mass-vector from any origin O would be the same as when A and B are in their actual positions. The point C is called the *Center of Mass* of A and B.

Center of Mass of a System.—If the system consists of any number of particles, we may begin by finding the center of mass of any two particles, and substituting for the two particles a particle equal to their sum placed at their center of mass. We may then find the center of mass of this particle, together with the third particle of the system, and place the sum of the three particles at this point, and so on till we have found the center of mass of the whole system.

The mass-vector drawn from any origin to a mass, equal to that of the whole system placed at the center of mass of the system, is equal to the sum of the mass-vectors drawn from the same origin to all the particles of the system.

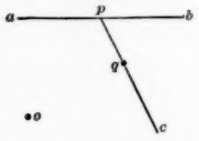
It follows, from the proof in "Center of Mass of Two Particles," that the point found by the construction here given satisfies this condition. It is plain from the condition itself that only one point can satisfy it. Hence the construction must lead to the same result, as to the position of the center of mass, in whatever order we take the particles of the system.

The center of mass is therefore a definite point in the diagram of the configuration of the system. By assigning to

the different points in the diagrams of displacement, velocity, total acceleration, and rate of acceleration, the masses of the bodies to which they correspond, we may find in each of these diagrams a point which corresponds to the center of mass, and indicates the displacement, velocity, total acceleration of the center of mass.

MOMENTUM REPRESENTED AS THE RATE OF CHANGE OF A MASS-VECTOR.—In the diagram of velocities, if the points o, a, b, c, correspond to the velocities of the origin O and the bodies A, B, C, and if p be the center of mass of A and B placed at a and b respectively, and if q is the center of mass of A+B placed at p and C at c, then q will be the center of mass of the system of bodies A, B, C, at a, b, c, respectively.

FIG. 8.



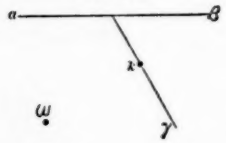
The velocity of A with respect to O is indicated by the vector $\overline{o\,a}$, and that of B and C by $\overline{o\,b}$ and $\overline{o\,c}$. $\overline{o\,p}$ is the velocity of the center of mass of A and B, and $\overline{o\,q}$ that of the center of mass of A, B, and C, with respect to O.

The momentum of A with respect to O is the product of the velocity into the mass, or $\overline{o\,a}$.A, or what we have already called the mass-vector, drawn from o to the mass A at a. Similarly the momentum of any other body is the mass-vector drawn from o to the point on the diagram of velocities corresponding to that body, and the momentum of the mass of the system concentrated at the center of mass is the mass-vector drawn from o to the whole mass at q.

Since, therefore, a mass-vector in the diagram of velocities is what we have already defined as a momentum, we may state the property proved in "Center of Mass of a System," in terms of momenta, thus: The momentum of a mass equal to that of the whole system, moving with the velocity of the center of mass of the system, is equal in magnitude and parallel in direction to the sum of the momenta of all the particles of the system.

EFFECT OF EXTERNAL FORCES ON THE MOTION OF THE CENTER OF MASS.—In the same way in the diagram of Total Acceleration the vectors $\overline{\omega\,\alpha}$, $\overline{\omega\,\beta}$, drawn from the origin, represent the change of velocity of the bodies A, B, &c., during a certain interval of time. The corresponding mass-vectors, $\overline{\omega\,\alpha}$.A, $\overline{\omega\,\beta}$.B., &c., represent the corresponding changes

FIG. 9.



of momentum, or, by the second law of motion, the impulses of the forces acting on these bodies during that interval of time. If k is the center of mass of the system $\overline{\omega\,k}$ is the change of velocity during the interval, and $\overline{\omega\,k}$ (A+B+C) is the momentum generated in the mass concentrated at the center of gravity. Hence, by "Center of Mass of a System," the change of momentum of the imaginary mass equal to that of the whole system concentrated at the center of mass is equal to the sum of the changes of momentum of all the different bodies of the system.

In virtue of the second law of motion we may put this result in the following form:

The effect of the forces acting on the different bodies of the system in altering the motion of the center of mass of the system is the same as if all these forces had been applied to a mass equal to the whole mass of system, and coinciding with its center of mass.

THE MOTION OF THE CENTER OF MASS OF A SYSTEM IS NOT AFFECTED BY THE MUTUAL ACTION OF THE PARTS OF THE SYSTEM.—For if there is an action between two parts of the system, say A and B, the action of A on B is always, by the third law of motion, equal and opposite to the reaction of B on A. The momentum generated in B by the action of A during any interval is therefore equal and opposite to that generated in

A by the reaction of B during the same interval, and the motion of the center of mass of A and B is therefore not affected by their mutual action.

We may apply the result of the last article to this case and say, that since the forces on A and on B arising from their mutual action are equal and opposite, and since the effect of these forces on the motion of the center of mass of the system is the same as if they had been applied to a particle whose mass is equal to the whole mass of the system, and since the effect of two forces equal and opposite to each other is zero, the motion of the center of mass will not be affected.

First and Second Laws of Motion.—This is a very important result. It enables us to render more precise the enunciation of the first and second laws of motion, by defining that by the velocity of a body is meant the velocity of its center of mass. The body may be rotating, or it may consist of parts, and be capable of changes of configuration, so that the motions of different parts may be different, but we can still assert the laws of motion in the following form:

Law I. The center of mass of the system perseveres in its state of rest, or of uniform motion in a straight line, except in so far as it is made to change that state by forces acting on the system from without.

Law II. The change of momentum of the system during any interval of time is measured by the sum of the impulses of the external forces during that interval.

Method of Treating Systems of Molecules.—When the sytem is made up of parts which are so small that we cannot observe them, and whose motions are so rapid and so variable that even if we could observe them we could not describe them, we are still able to deal with the motion of the center of mass of the system, because the internal forces which cause the variation of the motion of the parts do not affect the motion of the center of mass.

By the Introduction of the Idea of Mass we pass from Point-Vectors, Point Displacements, Velocities, Total Accelerations, and Rates of Acceleration, to Mass-Vectors, Mass Displacements, Momenta, Impulses, and Moving Forces.—In the diagram of rates of acceleration (Fig. 9, "Effect of External Forces on the Motion of the Center of Mass)," the vectors ωa, $\omega \beta$, &c., drawn from the origin, represent the rates of acceleration of the bodies A, B, &c., at a given instant, with respect to that of the origin O.

The corresponding mass-vectors, $\omega a.A$, $\omega \beta.B$, &c., represent the forces acting on the bodies A, B, &c.

We sometimes speak of several forces acting on a body, when the force acting on the body arises from several different causes, so that we naturally consider the parts of the force arising from these different causes separately.

But when we consider force, not with respect to its causes, but with respect to its effect—that of altering the motion of a body—we speak not of the forces, but of the force acting on the body, and this force is measured by the rate of change of the momentum of the body, and is indicated by the mass-vector in the diagram of rates of acceleration.

We have thus a series of different kinds of mass-vectors corresponding to the series of vectors which we have already discussed.

We have, in the first place, a system of mass-vectors with a common origin, which we may regard as a method of indicating the distribution of mass in a material system, just as the corresponding system of vectors indicate the geometrical configuration of the system.

In the next place, by comparing the distribution of mass at two different epochs, we obtain a system of mass-vectors of displacement.

The rate of mass displacement is momentum, just as the rate of displacement is velocity.

The change of momentum is impulse as the change of velocity is total acceleration.

The rate of change of momentum is moving force, as the rate of change of velocity is rate of acceleration.

Definition of a Mass-Area.—When a material particle moves from one point to another, twice the area swept out by the vector of the particle multi-

plied by the mass of the particle is called the mass-area of the displacement of the particle with respect to the origin from which the vector is drawn.

If the area is in one plane, the direction of the mass-area is normal to the plane, drawn so that, looking in the positive direction along the normal, the motion of the particle round its area appears to be the direction of the motion of the hands of a watch.

If the area is in one plane, the path of the particle must be divided into portions so small that each coincides sensibly with a straight line, and the mass-areas corresponding to these portions must be added together by the rule for the addition of vectors.

ANGULAR MOMENTUM.—The rate of change of a mass-area is twice the mass of the particle into the triangle, whose vertex is the origin and whose base is the velocity of the particle measured along the line through the particle in the direction of its motion. The direction of this mass-area is indicated by the normal drawn according to the rule given above.

The rate of change of the mass-area of a particle is called the Angular Momentum of the particle about the origin, and the sum of the angular momenta of all the particles is called the angular momentum of the system about the origin.

The angular momentum of a material system with respect to a point is, therefore, a quantity having a definite direction as well as a definite magnitude.

The definition of the angular momentum of a particle about a point may be expressed somewhat differently—as the product of the momentum of the particle with respect to that point into the perpendicular from that point on the line of motion of the particle at that instant.

MOMENT OF A FORCE ABOUT A POINT.—The rate of increase of the angular momentum of a particle is the continued product of the rate of acceleration of the velocity of the particle into the mass of the particle into the perpendicular from the origin on the line through the particle along which the acceleration takes place. In other words, it is the product of the moving force acting on the particle into the perpendicular from the origin on the line of action of this force.

Now the produce of a force into the perpendicular from the origin on its line of action is called the Moment of the Force about the origin. The axis of the moment, which indicates its direction, is a vector drawn perpendicular to the plane passing through the force and the origin, and in such a direction that looking along this line in the direction in which it is drawn, the force tends to move the particle round the origin in the direction of the hands of a watch.

Hence the rate of change of the angular momentum of a particle about the origin is measured by the moment of the force which acts on the particle about that point.

The rate of change of the angular momentum of a material system about the origin is in like manner measured by the geometric sum of the moments of the forces which act on the particles of the system.

CONSERVATION OF ANGULAR MOMENTUM.—Now consider any two particles of the system. The forces acting on these two particles, arising from their mutual action, are equal, opposite, and in the same straight line. Hence the moments of these forces about any point as origin are equal, opposite, and about the same axis. The sum of these moments is therefore zero. In like manner the mutual action between every other pair of particles in the system consists of two forces, the sum of whose moments is zero.

Hence the mutual action between the bodies of a material system does not affect the geometric sum of the moments of the forces. The only forces, therefore, which need be considered in finding the geometric sum of the moments are those which are external to the system—that is to say, between the whole or any part of the system and bodies not included in the system.

The rate of change of the angular momentum of the system is therefore measured by the geometric sum of the moments of the external forces acting on the system.

If the directions of all the external forces pass through the origin, their moments are zero, and the angular mo-

mentum of the system will remain constant.

When a planet describes an orbit about the sun, the direction of the mutual action between the two bodies always passes through their common center of mass. Hence the angular momentum of either body about their common center of mass remains constant, so far as these two bodies only are concerned, though it may be affected by the action of other planets. If, however, we include all the planets in the system, the geometric sum of their angular momenta about their common center of mass will remain absolutely constant, whatever may be their mutual actions, provided no force arising from bodies external to the whole solar system acts in an unequal manner upon the different members of the system.

STEEL SHIPS.

From "The Nautical Magazine."

For some years past, naval architects have been looking forward to the period when steel would definitely take the place of iron in shipbuilding, and it is now said that we are on the eve of the change. When some years ago steel was talked of, which would take a breaking-strain of over fifty-tons to the square inch, it was thought that ships might be built of half the weight of material required in the case of iron. The strong steel was tried and found to be altogether unreliable, plates with no perceptible fault would suddenly break after they had been riveted up in the ship, and altogether the material was pronounced to be of such uncertain character as to be unfit for shipbuilding. Since that time, however, another kind of steel has been introduced, and now vessels have been built of it for the Admiralty and for the merchant service, and recently the Committee of Lloyd's Register have issued a circular on the subject, giving the general conditions under which it may be used, and the percentage of reduction in the scantlings for iron ships which may be allowed when steel is substituted for iron. It is now said that *mild* steel may be made as reliable as wrought-iron, but the idea of doing with half the weight of material and having a breaking-strain of fifty-tons to the square inch has been abandoned; the steel now used takes a breaking-strain of about twenty-seven tons, and a reduction of twenty per cent. in scantlings is the extent of what is to be allowed for it.

It may, perhaps, be as well for us to preface our remarks upon the question of steel ships by a few words upon the difference between iron and steel, or rather the metal to which the latter terms has hitherto been applied. In most of the methods in use for extracting iron and steel from the ores, the first part of the process has had for its object the production of pigs of cast-iron. This is only of use for castings; it cannot be welded or otherwise worked, owing to the presence of impurities of which the chief are silicon, sulphur, phosphorus, and carbon. These substances are found in very variable proportions in cast-iron, the last named, however, usually constitutes two to five per cent.

Wrought-iron is mostly obtained from cast-iron by processes having for their object the removal of these substances, the name "wrought-iron" being restricted by metallurgists to the metal capable of being welded and containing less than $\frac{3}{10}$ per cent. of carbon. Even when there is more than $\frac{2}{10}$ per cent. of carbon, the metal is spoken of as a "steely" iron. The process by which wrought-iron has usually been produced from cast-iron, is known as "puddling," the pigs are melted in a furnace where they are apart from the fuel, and the fluid mass is exposed to the action of oxygen, partly obtained from the air, partly by having stirred up with it powdered iron ore, rich in oxygen. The temperature of the puddling furnace is so moderated that the iron, as it is freed from its impurities, becomes pasty and then solidifies, the melting point of pure

iron being much higher than that of the alloys which constitute pig-iron. The process of puddling has usually been accomplished by manual labor, and the wrought-iron which is drawn from the furnace in the shape of balls is not of the same character throughout, owing to its having been produced in a pasty condition. The presence of cinder and other imperfections, is also said to cause that want of homogeneity which produces the appearance of "grain" or fibre in wrought iron. The fibre is, of course, drawn out by the subsequent processes of hammering and rolling, by which plates and angle irons are manufactured from the puddled balls. The term *steel* has been applied to an alloy of iron intermediate in character between wrought-iron and cast-iron. In works on metallurgy, it is usually stated that when iron is alloyed with carbon to the extent of over three and under eighteen or twenty parts in the thousand, the metal takes the name of steel. The characteristic properties of steel, however, are, that it is malleable like wrought-iron, and that if it be heated, and then plunged into a cold fluid, it is hardened by such treatment,—in other words it can be *tempered*. The quality of steel is more injuriously affected by the presence of impurities than is that of wrought iron. Thus it is stated, that pure steel, with as much as three per cent. of carbon, is a malleable metal, but Bessemer steel, in which there is present but a very small proportion of silicon, is not malleable when the percentage of carbon exceeds two. For this reason it has been usual to make steel from wrought-iron, the metal being first decarburized and purified, and then a proportion of carbon reintroduced. The best kinds of steel are so made now, and previous to the introduction of the Bessemer process, all steel made in England was made from wrought-iron. In the Bessemer process steel is made directly from pig-iron, which is melted and run into a large heated vessel called a "converter" where a blast of air is passed through it, and the carbon and silicon are thus burnt out. When this is accomplished, a quantity of *spiegeleisen*, a cast-iron which contains a definite percentage of carbon, and which at the same time is free from deleterious matters, is introduced in a molten state, and the mixed metal is then cast in moulds. A material can thus be produced with any required percentage of carbon. Latterly, a specially prepared alloy, known as ferro-manganese, has been used in place of speigeleisen in the manufacture of some kinds of steel. In another method, known as the Siemens-Martin process, steel is made from pig-iron, speigeleisen, and steel or iron scraps in a special kind of furnace called the "Open Hearth," the distinguishing peculiarity of which is that the flame of coal-gas is made to play upon the metal. This process is much slower than the Bessemer, and was at one time thought to be more exact, it being practicable to take out samples of the metal from time to time, and ascertain its degree of carburization. The metal known as *mild steel*, the employment of which in shipbuilding is the subject of this article, was first manufactured for shipbuilding purposes by the Siemens-Martin method, and it was said that the necessary exactness in composition could not be secured by the Bessemer process, but it is now made in both ways with equally good results. At some steel works both methods are adopted, and we may suppose the cost of production, and the material produced, are the same in each case, from the fact that in one parcel of plates, specimens of both processes are frequently mixed.

If the name *steel* be restricted to metal containing the percentage of carbon mentioned, or to metal capable of being tempered, the so-called "mild steel" is not steel at all, but is really a kind of wrought-iron manufactured by the same process as steel, differing from ordinary wrought-iron by its greater purity, and by being homogeneous, that is by having no *grain*. Instead of being refined in a pasty form, it is refined as a liquid and cast in ingots, and the names "ingot iron" and "homogeneous iron" have both been proposed for it, but it has received the name of "mild steel," and appears likely to keep it. The proportion of carbon in *mild steel* is said to be generally less than $\frac{1}{10}$ per cent., and very rarely as much as $\frac{2}{10}$ per cent., while puddled wrought-iron frequently contains $\frac{2}{10}$ per cent. of carbon. Some manufacturers attribute the peculiar qualities of the metal to the presence of

manganese; others say that although manganese is most useful in the progress of manufacture, it is often almost absent in the finished metal, and when present is of no benefit to it. There is, however, so much diversity of opinion, that all that can be said with certainty is that a metal has been produced in large quantities by modifications of methods used to manufacture steel, that this metal is homogeneous, being equally strong in every direction, and that it has a higher breaking strain than any variety of commercial wrought-iron. It would appear then that after all we have not yet obtained a real ship-steel, but only a superior iron made by steel process, and called by courtesy *mild steel*.

Our own Admiralty may claim the credit of introducing mild steel for shipbuilding purposes in England. The French Government had used steel in the construction of ironclads; and in 1874 Mr. Barnaby, of the Admiralty, visited the French dock-yards and inspected several ships which were being built of it. The masted ironclad *Redoutable* was then building at L'Orient, and in her, steel was used for frames, beams, deck plating, plating behind armor and inner bottom; while the outer bottom plating and the rivets were of iron. The *Tempête* at Brest, and the *Tonnerre* at L'Orient, were also building, and steel was being similarly used in them, the steel for all these ships being manufactured at Creusot and Torre Noire. This metal took a breaking tensile strain of 30½ to 31½ tons per square inch, and the tested pieces elongated before fracture to the extent of 22 per cent. All the frames were bent by pressure, no iron hammers were used, and, if plates had been subjected to even light blows, they were immediately annealed. The cost of the angle steels was £27 per ton. A material which required to be so tickled with copper hammers, and was altogether of such a delicate character, was obviously unfit for shipbuilding, even in the Royal dockyards, where precautions might be possible which were altogether out of the question in a merchant ship yard. The solution of the difficulty was obtained in the production of a milder steel, which has been found by the Admiralty to be a thoroughly reliable material; but it must be observed that they have instituted a most rigid system of tests to make sure that not only every lot of plates, but *every plate* supplied to them is what it professes to be. The metal first used for the Royal Navy was manufactured by the Siemens process, at the Landore Works, near Swansea, and was employed in the building of the *Iris* and *Mercury* at Pembroke Dock. These ships are unarmored dispatch vessels, of 3,750 displacement tons, and it was desired to build them of very light material, in order to obtain the high speed of 17½ knots. They have longitudinal and transverse frames, and the bottom plating varies from ⅜ inch to ½ inch. All the shell of the vessel, with the exception of the heel, stem, sternpost, and rivets, is of steel. The screw shafting which is hollow, is made of Whitworth compressed steel, and the barrel parts of the boiler shells are of mild steel. The frames were bent hot, and afterwards annealed; but the plates were, as far as practicable, bent cold. The Admiralty have now six corvettes, of which the *Comus* is the type, building on the Clyde, in which steel is used for the plating, the frames being of iron; the masts also are to be of steel. Within the last year several merchant vessels have been laid down in which mild steel is to be largely used; and Messrs. Thompson, of Glasgow, are now building a steel ship with steel rivets.

We have before adverted to tests instituted by the Admiralty for the purpose of securing uniformity in the material. It has always been the custom of the Admiralty to subject iron made for them to a series of rigid tests, which in the early days of their iron ship-building were carried out at the place where the vessels were built, and one clause of every contract with a shipbuilder was that he should provide on his premises an efficient testing machine. As a result of this the Admiralty are at present paying £15 to £16 per ton for (B) iron, used by them for shipbuilding, the market price of ordinary ship iron plates being less than half this amount. Besides the tensile test, hot and cold bending tests have been applied to both plates and angle irons. Of late years the tests have been made at the manufacturers, and have been conducted by

inspectors appointed for the purpose. The Admiralty had thus at hand a staff and an organization which could, with some extension, be made available for testing the new material. Their tests for *mild* steel have consisted of:

1. The tensile test, the minimum breaking strain per square inch to be twenty-six tons, the maximum thirty tons per square inch; the elongation before breaking to be not less than twenty per cent. in a length of eight inches.

2. That after having been heated and then cooled in water of a temperature not higher than 60° Fahrenheit, the steel shall stand bending to a curve of which the inside diameter is to be three times the thickness of the plate. A shearing is taken from *every* plate, not less than an inch and a half wide, and tested in this manner.

We have seen a list of consecutive tests of steel for Admiralty vessels of the *Comus* class, comprising eighteen plates tested with cuttings lengthwise and crosswise for tensile strength. The breaking strain was as often higher as lower for the crosswise cutting than for that taken lengthwise and varied from 25-6 to 32-8 tons per square inch; the elongation varied from 12 to 32 per cent., being for the most part well above the prescribed 20 per cent.

Turning now to the Mercantile Marine, and first to the action of Lloyd's Registry, we find that until November last there was no defined rule as to the employment of steel in shipbuilding, but each case was considered separately. In November, however, a report was published stating that a visitation committee had recently inspected the steel vessels building for the Admiralty, as well as others building for classification, and had also visited some of the leading steel works. As the result of their inquiries a circular was issued stating the conditions under which mild steel might be used as a material for shipbuilding. These are, first, that a midship section, &c., showing details of scantlings, be submitted in every case, and that tensile and other tests may be employed by the surveyors, every plate being supposed to take a minimum tensile breaking strain of twenty-seven, and a maximum of thirty-one tons to the square inch, with twenty per cent. of elongation previous to fracture. It was further prescribed that strips should, if heated and then cooled in water at 82° Fahrenheit, stand a similar bending to that of the Admiralty test.

In these requirements it will be noticed that the tensile strain is increased one ton, a difference justified by the practical results of testing. Further, it will be seen that an important feature of the Admiralty tests, the bending of a strip from *every* plate was omitted, the bending tests being only applied at the discretion of the surveyors. This omission was supplied by the issue of an amended circular on the 20th December, in which it is prescribed that all ship steel shall be marked by the manufacturers with a special brand, to indicate that strips from each plate so marked have been submitted to the bending test.

We cannot but think that the alteration in the amended circular was a wise and necessary measure. Former experience in metal made by steel processes has taught the naval architect that while a parcel of plates may for the most part be of excellent quality, and capable of doing their work in the structure of the ship, others made by the same process, and which show no outward difference, may be very faulty, and what makes the matter still worse is the risk that the fault may not show out till the plate is riveted in the ship. Manufacturers have been pretty successful hitherto with the new metal, but there is much yet to be learned before the manufacturer can be certain of producing parcels of material uniform in quality, and the naval architect must have much more experience of it before he can with prudence consent to make reductions in scantlings proportioned to the claims as to strength put forward; indeed, before any reduction at all can be made there must be some guarantee such as the brand proposed, that pains have been taken to ensure that *every* plate possesses the distinguishing characteristic of mild steel. As over-stepping the limit of safety in any particular may involve the loss of the ship, we would commend the whole subject to the notice of the Board of Trade, and to such of its officers as have practical shipwright experience, who cannot at this juncture give too much attention to the proper-

ties of the new material with which they will certainly have to deal. In fact, to vessels which come under the Passengers Act the benefit of a reduction in scantlings will be of most advantage, and we may feel sure that in building vessels of this class the conditions will be frequently complied with, and any consequent reduction of scantlings taken advantage of.

The advantage given for the use of steel instead of iron is to be a general reduction of scantlings to the extent of twenty per cent., subject to modifications in each case, consequent upon special considerations. Assuming the minimum tensile strength of iron used in shipbuilding at twenty tons per square inch, and the strength of the new material at twenty-six, a reduction of twenty-three per cent. in scantlings would secure the same strength; it will be found, however, that most mild steel will be over twenty-eight, and we think iron ship plate is often under twenty; and it will thus be seen that the Register Committee have secured a good margin, and are, as is most desirable, on the safe side. Already, as might perhaps be expected, complaints have been made that this reduction is not as much as would fairly meet the case, and that the requirements as to testing will cause much inconvenience. In the number of *Engineering* for 28th December last is a letter from a Clyde shipbuilder, in which he states that on a proposal for building a steel steamer the reduction of twenty per cent. was only granted for a portion of the structure, and that in some cases much less (14¾ per cent. for the plating of botttom and sides) was allowed. He also complains of the regulations as to testing. The Committee have requested their surveyors to ascertain and report, "as early as possible, what facilities exist in the yard of the builders of this vessel for carrying out the tests required by the Committee in accordance with the circular." The writer goes on to say that "Lloyd's Committee know well there is not a testing machine in one out of a hundred shipbuilding yards in the kingdom," and then exposes the inconveniences which must result from testing and rejecting plates after they have arrived on the shipbuilder's premises, and urges that if the tests are to be carried out at all, the best plan will be to provide for making them at the steel works.

The present provision for testing iron is contained in Section 3 of Lloyd's Rules for Iron Ships, and runs thus:

"Section 3.—The whole of the iron to be of a good malleable quality, to be subjected to tests at the discretion of the surveyors. Brittle or inferior material to be rejected. All plates, beam, or angle iron to be legibly stamped in two places with the manufacturer's name or trade mark, and the place where made, which is also to be stated in the report of survey."

It would appear by this that no tensile tests were contemplated by the rules, and as a matter of fact, but little more has been usually done in the way of testing iron than observing the way in which the material stood punching and bending, during which process, if it were of very inferior quality some indications of its badness would certainly appear. If, however, *mild* steel is largely used in shipbuilding, a series of rigid tests must of necessity be applied.

A comparatively small variation in the quantity of carbon or the presence of impurities is all the difference between mild steel and the unreliable material made by the same process, and this difference can, for practical purposes, only be ascertained by the tempering test which is to be applied to every plate, and which appears to be essential in steel shipbuilding. These tests must cause the market price of steel to be higher than would otherwise be the case, but there is no reason why it should be so much dearer than iron as has been anticipated. We believe the Admiralty have paid £15 per ton for their mild steel. That is less than they are paying for (B) ship plates, and we think there is every reason to believe that, with an increased demand, mild steel can be manufactured at a much lower rate. Its extended substitution for iron in shipbuilding will, of course, depend upon its price, whether it will be only so much dearer than iron, that the additional sum spent in first cost will be paid for by increased freight owing to the less weight of hull.

Another consideration connected with the use of steel for shipbuilding is its

durability as compared with iron. Of this, little can be said at present. Experiments have been made to find out the extent of corrosion in salt-water of steel and iron, but it is difficult to reproduce the conditions which obtain in actual ships, and it may be said that we know nothing for certain on the subject. Obviously, corrosion is a more important factor in steel than in iron ships. In the former the material in the first instance being thinner, the same amount of wasting will reduce the strength by a larger percentage. We have heard that in some of the very thin steel steam-launches recently built for high speed, deterioration of the material has arisen from an unexpected source. It was observed that the plates were pitted outside the vessel, and as they were only a sixteenth thick the pitting was nearly through them. No cause could be assigned for it except that the black oxide which forms upon the plate in rolling was electro-negative with regard to steel-plates, and thus galvanic action was set up. This may, of course, be prevented by "pickling" the plates in a diluted acid, and so removing all the black oxide before using them. We have heard that the Admiralty, with a view to provide against galvanic action from this or other causes, intend to "galvanize," that is, coat with an alloy of zinc and iron, all outside plates for ships. They can thus make certain that while there is any zinc alloy left, no galvanic action will affect the iron or steel; the only question is, whether the coating process will not injure the metal in other ways.

The Admiralty have not yet used mild steel rivets. They have, however, been used in shipbuilding on the Clyde, and it is said with good results. In one respect they are said to be superior to iron rivets as they hold the heat longer. It is urged against their use that they are liable to be spoilt by being over-heated or "burnt," when they become brittle and lose their malleability. With reference to this, the report of Lloyd's surveyors points out that iron rivets may also be spoilt, although at a higher temperature, and there is this advantage with steel rivets, that they unmistakeably show when they are bad and cannot then be used at all. It would appear probable that steel rivets may be harder than iron ones, and would thus be liable to suffer from jarring strains, but we think on the whole it will be found best to use metal for rivets, of the same kind as the plates. One thing we would suggest; seeing that galvanic action appears to take place between metals of but slightly different composition, it may probably occur between steel plates and iron rivets and the result would be most serious.

The experience of the next few years will probably decide whether ingot iron made by steel processes will take the place of puddled iron as a material for shipbuilding. As the new material becomes better known it will become evident to what extent it may be trusted, and it is possible that our experience of it may justify a further step, the use of a decided steel with a high tensile strain as a material for shipbuilding. This must depend upon steel makers themselves; whether they can give the shipbuilder a thoroughly workable material with high tensile strain at a moderate cost, and above all a material which can always be trusted. The naval architect has a higher responsibility than the designer of land structures in which faults detected may be remedied at once; his work is subjected to severe and repeated strains, and must be capable of enduring them often for long periods. This is the reason why he will hesitate to use a material about which others may have no misgivings, and when he does use it, will exact good guarantees for its reliability.

Since the foregoing article was written, a further report of Lloyd's Special Committee has been published, from which we quote the following as enforcing our remaks upon the dangers attending the use of the new material unless every plate be tested:

"A most striking example was shown us at one of the works we visited, of the necessity for a bending test being applied to a shearing from every plate; and it also afforded a proof that the best test to apply would be a temper test, instead of an ordinary cold test. The firm in question was at the time manufacturing both soft and hard steel-plates, and in passing through the rolls a hard plate became substituted for a soft one. After passing through the rolls the

plates were annealed before being sheared, and when, after shearing, the hard plate came to be tested by the temper test, instead of the plate bending to the required curve, it broke off short. This led to the marks on the plate being examined, when the source of error was discovered. It had come from a charge capable of standing thirty six tons to the square inch, and was never intended to be used for soft steel-plates."

The Committee also urge the importance of the tensile tests being made with pieces of uniform length, the twenty per cent. elongation is to be in a length of eight inches, and if shorter pieces be tested, the percentage of elongation should be greater, since the elongation is greatest near the point of fracture, and thus a large percentage would be obtained in a short than in a long specimen of the same material. With regard to rivets, the last report of the Committee recommend that the steel employed in them should be very mild, and have the lowest limits of tensile strength.

RIVER IMPROVEMENTS IN FRANCE, INCLUDING A DESCRIPTION OF POIRÉE'S SYSTEM OF MOVABLE DAMS.

By Prof. WILLIAM WATSON, Ph. D., late U. S. Commissioner.

Within a few years there has been established between Paris and Auxerre a continuous system of navigation, with a minimum depth of water of 1.60 meters.

This has been accomplished by the erection of thirty four movable dams with side locks, and also making three cuts-off: each cut-off has a guard gate at its head to keep out the flood water, and a movable dam without a lock is built across the river just below each gate.

The above operations have served to convert the two rivers, the Seine and the Yonne, into a series of navigable pools. Rivers so converted are said to be canalized.

In order to fully appreciate the importance of the improvement of the navigation by the establishment, on a large scale, of movable dams above Paris, it will be necessary to explain briefly the method of navigation heretofore in use on these rivers.

Formerly the water was raised in different portions of the river by means of movable dams (the construction of which will be presently explained); a part of one of these dams being suddenly removed, an artificial flood, called an écluseé or flash, was formed, which, in passing, afforded for a limited time, a draught of water sufficient for navigation.

The instant for opening each movable dam was determined by an empirical rule which was closely followed, and each dam was closed after the water had fallen below a certain level; usually during the summer, they were opened twice per week.

The velocity of a flash depends upon the declivity and sinuosity of the river, the number of dams, the volume of the flash itself, the wind, and the obstructions of the stream.

The boats carried by the flash generally go more rapidly than the flash itself, so that they can make short stops, to receive or discharge freight, and take the same flash again.

To understand the form and motion of a flash it is necessary to observe its velocity and depth throughout its whole extent; this has been done by M. Chanoine, at Laroche, and is shown in Fig. 1. This figure gives the level of each point of the longitudinal profile with its corresponding velocity. It shows that the velocity varies from one point to another, and that the top of the flash travels more rapidly than any other point, whether before or behind it. For this especial flash the velocity of the water is 1.33 meters per second for a length of 2,394 meters occupied by the top, while at 3,474 meters in front the velocity is only 0,53 meter; and it is 1.15 meters at 4,482 meters behind; thus at each in-

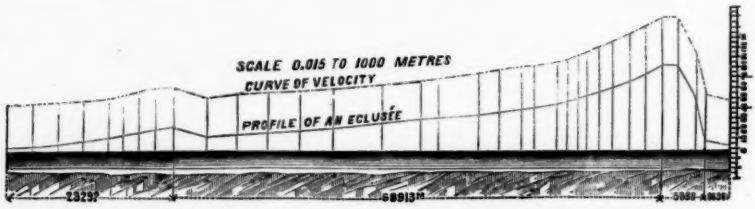


FIG. 1. — Form of an *éclusée* or flash. Curve showing its velocity at each point.

BASSEVILLE BARRAGE.

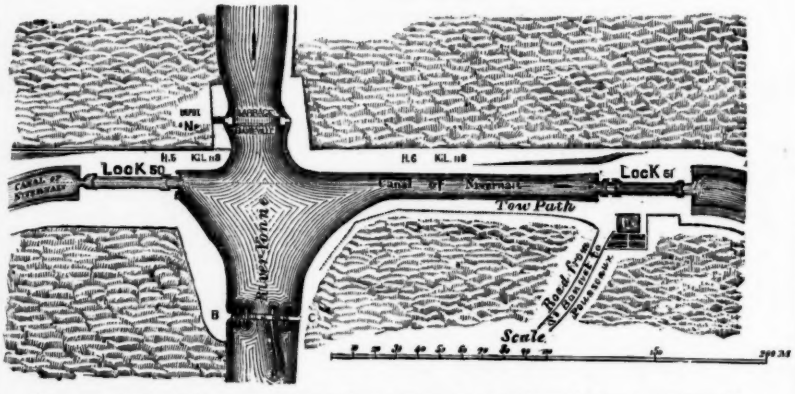


FIG. 2. — Plan of the crossing of the Yonne River, by the Nivernais Canal at Basseville.

FIG. 3. — Elevation of the Basseville barrage, showing half the barrage closed with the fermettes raised, and the other half open, with the fermettes lowered.

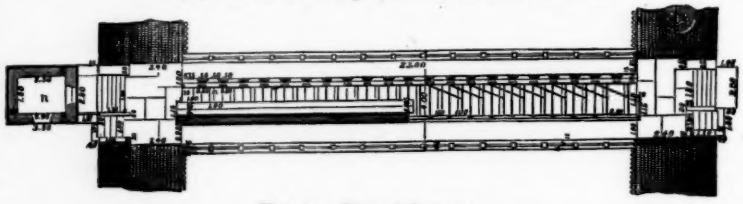


FIG. 4. — Plan of the same.

stant the highest section of the flash is thrown forward upon the section immediately preceding, which moves at a slower rate. This shows why a boat on the top of the flash will move faster than the flash; but if the boat is in that part of the flash where the velocity is less than 1 meter and behind the crest it moves slower than the flash and finally falls entirely behind it. We may estimate the effective duration of a flash to be one-half the time it actually takes to pass a fixed point.

Each movable dam remains open only a short time for the passage of the flash and is immediately closed again to collect the water for the following flash. This closing produces below the dam an abasement of the level of the water which is designated by the name *affameur*. Every flash is thus followed by an *affameur* which is felt at a great distance down the stream; and for from twelve to twenty-four hours following, the water is below its ordinary level; for this reason the ascending boats are nearly or quite empty. Nevertheless this navigation, imperfect as it is, has rendered for three hundred years signal service for the economical transportation of wood etc., at a time antecedent to the establishment of other means of easy and rapid communication. In 1866, from Laroche to Montereau, the freight in boats was 270,699 tons, by rafts 179,230, descending; ascending freight 5,518 tons; total 455,750 tons.

As early as the middle of the last century attention was called to the diminution of the volumes of the flashes, and the remedy proposed was the construction of large reservoirs to accumulate the winter waters, in order to augment the flashes in summer. One of these, the reservoir of Settons with a capacity of 23,000,000 cubic meters was finished in 1858, and supplied for each flash a volume of from 500,000 to 700,000 cubic meters. But this flash, augmented by the water from all the dams of the Yonne and its affluents above Auxerre, encountered no further obstacle below the latter point, and went on diminishing to the Seine, upon which its effect was very slight. Only half the appropriation had been spent when the inefficacy of the remedy was perceived. In reality the progress of industry and commerce, as well as the extension of railways, required the barges on the Seine and Yonne to be greatly improved, which was not possible until the navigation should be made continuous with a sufficient draught of water for loaded barges.

At this juncture the Government, adopting the views of M. Cambuzat, ordered the construction of the movable dams referred to at the beginning of this paper. These dams, or barrages as we may call them, are of several kinds, one of the simplest is Poirée's needle barrage known as *Barrage à fermette de M. Poirée.*

POIREE'S NEEDLE BARRAGE.

History.—The following is a brief outline of the history of the invention of this barrage. At Basseville, where the Nivernais canal crosses the Yonne at the same level (Fig. 2), it was necessary to erect a barrage, which, while it maintained the level of the river at a height sufficient for navigation, could be so opened as to leave the original section of the stream wholly free for the passage of flashes carrying rafts and logs.

The old passes of the Yonne gave M. Poirée his first idea; these passes were closed by a horizontal swinging beam supporting a vertical screen composed of a number of wooden battens called needles, each about 2 meters long and 0.475 meter square. Mr. Poirée first made a *projet*, consisting of five of these passes placed side by side; next he conceived the idea of replacing the piers which separated the passes, by iron frames placed parallel with the current; then he made these frames movable about their bases, so that in lowering them upon their bed, they should completely disappear, and thus leave the original section of the river intact; finally, he increased the number of the frames, and brought them close together in order to diminish the pressure which each had to sustain, and thus avoid any risk either of rupture or displacement. On account of the resemblance of these frames to the trusses of a roof (*fermes*) he called them *fermettes*, a name which they have since retained.

DESCRIPTION OF BASSEVILLE BARRAGE.

In order to give a clear idea of this barrage, I cannot do better than repro-

BASSEVILLE BARRAGE.

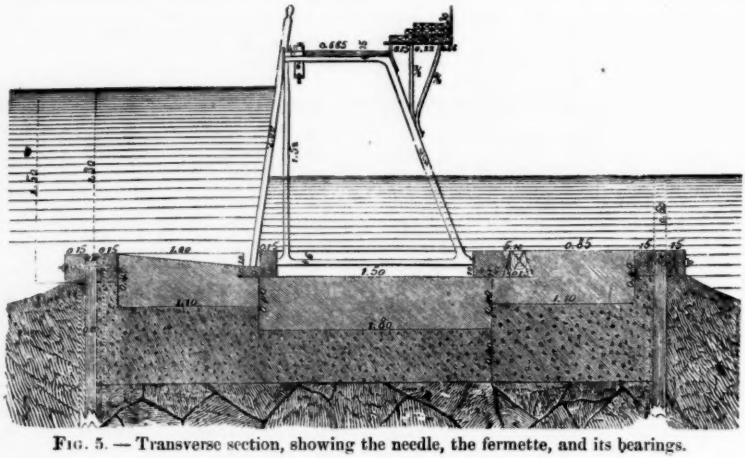
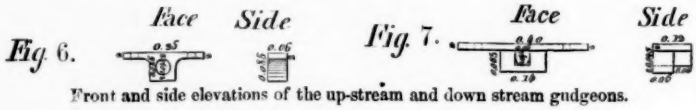
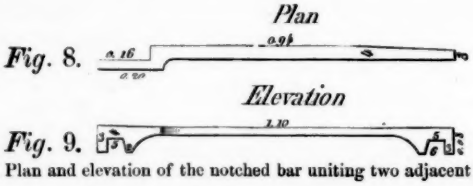


FIG. 5. — Transverse section, showing the needle, the fermette, and its bearings.



Front and side elevations of the up-stream and down stream gudgeons.



Plan and elevation of the notched bar uniting two adjacent fermettes.

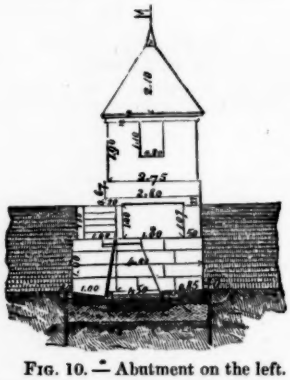


FIG. 10. — Abutment on the left.

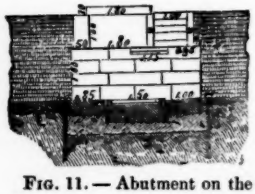


FIG. 11. — Abutment on the right.

BASSEVILLE BARRAGE.

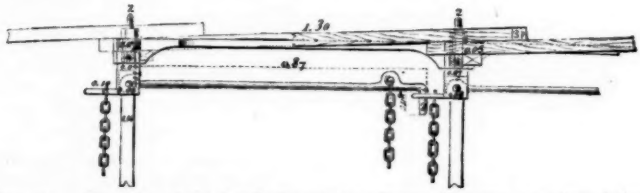


FIG. 12. — Elevation of the details for uniting adjacent fermettes, seen from below.

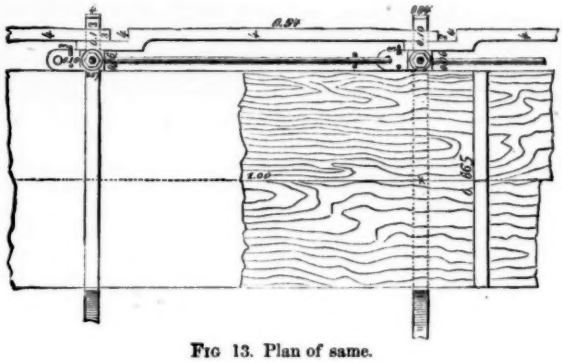


FIG 13. Plan of same.

Fig. 14. *D. Section on AB.*

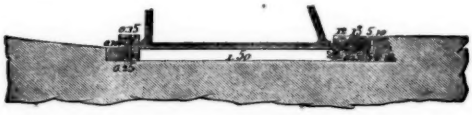


Fig. 15. *D. Plan*

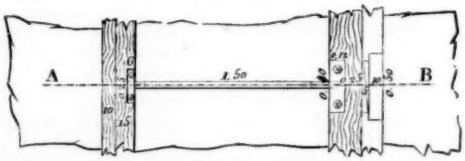


FIG. 14. — Transverse section of the gudgeons and bearings of a fermette.
FIG. 15. — Plan of the same.

duce a description given by the inventor, in a lecture at the School of Roads and Bridges at Paris: Figs. 2, 3, 4, 5, represent the situation and arrangement of the first needle barrage ever erected. It consists of a succession of iron frames (Fig. 5) called *fermettes*, placed parallel to the current and turning around their bases in bearings which are firmly attached to a carefully prepared bed. The *fermettes* when they are erect, are united by bars with jaws or notches at their extremities (Figs. 8 and 9). The needles form, by their union, a screen which rests below, against the sill, and at the top, against the fermette bars, placed near the level of the water, which the barrage is intended to maintain. Each *fermette* is trapezoidal; its bases are horizontal; the lower one is terminated by gudgeons which are secured by two cast iron bearings (Fig. 14). The upper bars support a foot-bridge used by the lockman to work the barrage (Figs. 5 and 13): the up-stream side is vertical, the down-stream side is inclined; the interior is strengthened by one or more braces according to the pressure it has to support.

At the head of the *fermettes* is a bolt with a washer at its upper part; against this bolt rests one end of one of the up-stream coupling bars (Figs. 8 and 9); the lower part of the bolt holds on one side an eye-bar (Figs. 12 and 13) into which fits the hook of the rod uniting this fermette with the preceding one, and on the other side the hooked rod which unites it to the succeeding *fermette*.

Weight and dimensions of a fermette.—In order that the *fermette* may be easily maneuvered by two men they are placed one meter apart: they are 1.52 meters high, 0.70 meter wide at the top, 1.50 meters at the base, and weigh 90 kilograms each—not including the bars and rods; the thickness of the iron is 0.04 meter.

The operations for closing the barrage are as follows:—Two men raise the first *fermette* by the chain which unites it to the abutment and put its hook into the eye-bolt fixed in the masonry; next they place the two planks of the flooring, and then connect the *fermette* on both sides with the abutment by means of the notched coupling bars; they operate in the same manner for the following *fermettes*.

Having thus established the frame the two men proceed to place the needles; first, at intervals, so as to break the current, then close together, so as to render the screen as tight as possible.

When it is required *to open the barrage*, the men remove the needles and place them upon the down-stream portion of the service bridge; if it is also required to lower the *fermettes* they carry the needles to their store-room *n* (Fig. 4); then they take off the coupling bars and the flooring of the last interval; next they raise the hook which unites the last *fermette* with the preceeding one, and lower it slowly to its place by means of the chain attached to the hook. The same operation is repeated for each interval.

When a *fermette* is lowered and its chain stretched tight, a peculiar ring-shaped link, previously placed at the proper distance, should be found at the right of the eye-bar of the upright *fermette;* if this is not the case, the lockman is warned that the *fermette* is not entirely down.

The time per running meter to raise the *fermettes* and place the needles is about 90 seconds:

To open the barrage by removing the needles 30 seconds:

To remove the needles and lower the *fermettes*, 50 seconds.

THE Alberta, Royal yacht, made a trial of her machinery lately in the Solent, when advantage was taken of the occasion to try a new log, the invention of Mr. Froude, with which it is intended to test the speed of vessels of war when undergoing their six hours' run. The log itself is not unlike the patent log known as Massey's, but the fan is much larger and has been formed upon strictly scientific principles. It was connected to a registering apparatus inboard by Kelway's electric gear, by means of which the work performed by the log in the water is recorded on deck, thus dispensing with the necessity of hauling in the log to ascertain the distance travelled through. As tested on the measured mile the error of the improved Massey was found to be only one-hundredth part of a knot.

A MORAL AND ECONOMIC ASPECT OF THE SEWAGE QUESTION.

From "The Builder."

NEW excitement about the sewage outfall and its effect on the Thames, has developed into a very pretty dispute (we will not say "quarrel") as it stands, even if it lead to no more definite result. In all such cases there is a certain amount of talk and recrimination to be got rid of, —a kind of waste gas driven off by combustion,—before we come to the solid matter of the point at issue,—the question, what is to be done? We may even yet be a good while in getting to any practical result; but it is something if we can even make a step or two in the direction of the right theory of action. What is, in fact, needed, in regard to this and some questions of social economy of the day, is to bring theory and practice into closer relation one with the other. The main drainage works for London were practically, no doubt, a great piece of engineering skill and perseverance, involving great outlay and much practical skill in investigating and testing materials so as to produce a permanent result; yet all this labor and expense is, as we think people are begining to see now, to a great extent, thrown away, through being based on a mistaken and incomplete theory to begin with.

Two points have struck us amid some of the paper warfare which has been started on the subject, by no means of equal importance, but which both serve to show the very partial view of the subject which is taken by those who are officially most concerned in it. One is, the exclusively legal aspect in which the matter is treated by the Board of Works or by those who are their spokesmen or champions before the public. One of these chivalrous defenders of the Board and its action seemed to think he had made quite a point in favor of his clients by showing that they had not, as some of their opponents asserted, contravened the provisions of the Rivers Pollution Act; that there was a clause in that Act specially exempting the case of the Thames and the main drainage works from its operation: furthermore, that it was a mistake to suppose that the Board of Works were under any obligation to deodorize the sewage before turning it into the river; except in regard to temporary outfalls until the main drainage outfall could be completed. But this is only proving a little too much: only, at the most, shifting the blame on to other and, perhaps broader shoulders; or possibly we may go further and say that such a fact only shows that the Board and their engineers were shrewd enough to obtain legal sanction for shirking the most serious part of the problem, in order to apply with greater readiness a remedy of which it might have been prophesied (was, in fact, prophesied) that it would work no radical cure. Looking at this defence, based on their legal position, one cannot help asking, under what exercise of influence in high places it came to pass that the Metropolitan Board of Works were permitted to form an exception to the operation of the Rivers Pollution Act in the case of the most important town on the most important river in England? The result simply comes to this, that the public and their Parliamentary representatives were deluded into the belief that a certain scheme, carried out at enormous cost, would prove an efficient solution of the question, "What is London to do with its sewage?" And that not only is it no solution, but is surely though slowly building up the original danger in a roundabout manner; but also that any exercise of common foresight on the part of those who carried out the scheme ought to have led necessarily to the conclusion that this would be the result. Yet, for all this, it seems to be considered a sufficient defence to say that the Board have done all that the law required of them. They do not recognize any moral or sanitary responsibility in the matter; they do not seem for a moment to entertain the idea that they, as the responsible body entrusted with the improvement of London, were under a moral obligation to find out the best method and carry it out; they have not

asserted, or their friends have not done it for them, that they consider the sewage difficulty on every side, went to the root of the matter, and saw no better solution than that which has proved such a failure,—not at all: they are content to say that they were under no legal obligation to find a solution; that, like "the unprofitable servant" in the parable, they had done that which it was their legal compact to do, their "duty" only in the narrowest and most official sense. But they cannot morally (whatever they may do legally) shelter themselves behind the law in this way. On such points the Board of Works, being specially and immediately charged with these great sanitary operations, were bound to know more about the subject than any one else, to correct or supply the defective requirements of the law, not to shelter their costly half-measures behind it. To adopt the latter position is as reasonable as it would be to say that a man deserved no blame for keeping a cesspool close to his house property, though knowing it to be a nuisance, because the sanitary inspector was deficient in knowledge, and did not compel him to remove it.

That this merely legal responsibility is the view taken by the Board of Works of their position, we have had further confirmation in the tone they have openly and explicitly adopted in regard to the almost more pressing question, because dealing with a more instant though transient evil, of the Thames floods; in regard to which they have drawn upon themselves something more than a hint from the Home Secretary that they may be compelled to do their duty or resign their privileges. But leaving this point at present, which we allude to only as confirming the justice of our strictures in regard to the slack sense of responsibility on the part of the Board, we must say a word on another aspect of the question which has been incidentally suggested, but deserves far more consideration than it seems likely to receive. Among the arguments brought forward to justify the legal position of the promoters of the main drainage works, the following quotation from the Local Government Report of last year has been adduced:—"That towns situated on the sea coast, or on tidal estuaries, may be allowed to turn sewage into the sea or estuaries, below the line of low water, provided no nuisance is caused; and that such mode of getting rid of the sewage may be allowed and justified *on the score of economy*." (The italics are our own.) The application of this to the particular question at issue is of course that Crossness comes under the conditions thus described in the Report. What we wish to draw attention to is the defence which is made of this way of getting rid of sewage as "economical;" and what is meant by that is (for in no other sense can it be true) that the particular town which gets rid of its sewage in this manner saves the cost of transportation of the sewage, and of the labor required for this, to a place where it can be made useful. Now, just consider what an utterly narrow and one-sided view of "economy" this is. Economy, if it means anything, means a wise saving and husbanding of resources, not the keeping of injurious things about one to save the cost of getting rid of them. Even as regards the special town which thus turns its sewage out on to its shores, there is, therefore, no real economy; a permanent danger to health is thus established, which in the case of a small town favorably situated in regard to tides, may, perhaps, be very slight, but which, it is to be remembered, is always tending to increase. But this economical statement of the matter becomes still more unphilosophical in its aspect when we take a broader view of the subject. No doubt it must be admitted that the golden promises about the national wealth to be derived from the utilization of sewage, which were too enthusiastically and prematurely made when the idea of utilization first occurred, can hardly be fulfilled; ratepayers must modify their ideas as to what can be expected in the way of return from that source, and as to the expenditure involved in it both relatively and positively. Still, there are the facts, which may now be taken as almost conclusively proved, that sewage is a nuisance and a danger when passed into rivers, or even into the sea in close proximity to a coast town, while it is innocuous when properly treated as manure; that in the former case it is clear loss, while in the latter case it has

a certain "food-producing" power not inconsiderable, though not equal to what used to be supposed. Admitting, therefore, all that has been urged against irrigation, that the farmers will not take the sewage, that it cannot be sold at remunerative prices, and so on,—it must nevertheless be concluded that if no return is obtained from irrigation, it is a wise economy notwithstanding to expend money in putting sewage where, at all events, it does good rather than harm, and making a step towards that ideal economy of physical science which is inferred in the saying that "dirt is only matter in the wrong place." And we may suggest in passing that if we can arrive at an organized system of sewage distribution over the land there is really no reason why the opposition of the farmers,—a class of the community always averse to novelty and not given to philosophize on the reasons of things,—should not be got over by compulsory legislation, just as reasonably as such legislation has been proposed in regard to the irrigation of India, both schemes being considered as concerned with the good of the people at large, to which private inclinations must bend. It is certain that, to carry the irrigation theory into practice in the case of sewage, and more especially in regard to London sewage, a systematized machinery of distributing on a large scale would be required; we say more especially in regard to London, because the amount to be dealt with is so great, and it would be necessary to provide for its distribution over so wide an area, the circumstances being quite different from those of an ordinary-sized town; and as it is pretty certainly ascertained that, at the worst, town sewage is more or less productive as a manure, and can be used in this way with effect in its agricultural results, and without being obnoxious in a sanitary point of view, the question to be considered is whether it is not worth while to set at once about the framing of a comprehensive system of sewage distribution, and the organization of the machinery of collection and transportation.

No doubt this will be a very costly operation to begin with, and will require not only machinery, but labor, the cost of the latter being a continuous item. And it is in reference to this point that we wish to recommend to those who think it so much more economical to run sewage into the sea, an aspect of the labor question, which is worth considering in connection with the subject. Society is dragged upon by the clog of a very large, and we fear not a decreasing, pauper population; a portion of which consists of those, no doubt, who would always be paupers by option, as long as our inconsiderate and ill-organized charities give them an easy means of being so; but of whom, again, there is a large proportion who would gladly work if work could be found for them. It is one of the greatest difficulties encountered by those who are specially concerned in the work of helping their poorer brethren, especially in the present "slack times," to find any work for those who are willing to work, and who would do anything rather than sink into pauperism. So great, indeed, is the difficulty, that there is even a temptation to, as we may say, *invent* work for these unfortunate classes, and thus save the outward aspect of pauperism, though in reality adopting another form of it. And therefore a work which requires to be done for the general good, and upon which those who are now perforce idle and dependent, could find the opportunity for selling their labor with advantage to themselves and the community, ought really to be considered almost a godsend. If it becomes necessary, therefore, to organize sewage distribution on a large scale (and without some regular and extensive system it can hardly be efficiently carried out), this might really also be a step towards that organization of labor on a large scale which is the only permanent remedy against the existence of distress and pauperism. And therefore it seems to us that when people talk of "economy" as an element in favor of the running of sewage to waste, they should take into account, *per contra*, not only the possibility that sewage distribution works may be made to pay their way if properly managed (and, in spite of some disappointments, the contrary is not proved), but also the opening afforded for employing labor on a great scale,—labor which is now idle,—in a way worth paying for in itself, and which would even recoup a great deal of

its own cost by the reduction of what now goes to the support, on charitable grounds, of those who have no sale for their labor: not to speak of the incalculable social advantage of being able to turn a number of idle hands to work which would be directly for the *wealth* (as distinguished from "riches") of the whole community. We have sought on more than one occasion to call public attention to the existence of "lands that want hands." The proper treatment of the sewage question would involve work that wants hands, and provide us with a very important and permanent counterbalance against the drag on society, to put it on no higher ground, of hands that want work.

ON TUBBING; OR STOPPING BACK FEEDERS OF WATER MET WITH IN SINKING SHAFTS.

By Mr. RALPH MOORE, H.M. Inspector of Mines.

From "Iron."

Tubbing is the name applied to a wood or iron lining placed in shafts for the purpose of stopping back water. The theory is that the porous sandstones found in the coal-measures are pervious to water coming in from the surface at their outcrops, while the clays or shales are impervious and will not allow water to pass through them; the sides of the shaft are therefore cased or lined where the water-bearing strata are met with, so that the water may not run into the shaft, and require to be pumped to the surface. Although the practice is frequently resorted to in English mining it has not been much adopted in Scotland, and it is thought that a short description of one of the methods of putting it in may not be unacceptable to the members of this Institution. The base of the tubbing is the wedging crib which consists of a hollow iron ring 16 inches broad and 6 inches deep, metal inch thick. It is cast in segments about 4 feet long, and the inside diameter is the same as that of the pit. The space between the wedging crib and the sides of the shaft is made water-tight with wooden wedges, and the wedging crib is the foundation of the whole structure.

Upon the wedging crib are placed plates or rings of tubbing. These are also made in segments, with flanges in 4 feet lengths, 2 feet deep, metal about $\frac{7}{8}$ of an inch thick, dependent on the pressure to be resisted. These rings of tubbing are piled one upon another as high as the water will rise behind it before finding its level.

The mode of putting in the tubbing is as follows:—The shaft to be tubbed is made circular, and before the tubbing is put in, the water met with is raised by pumping machinery in the usual way.

After the water-bearing strata have been sunk through, the wedging crib is laid in the first bed of hard "faikes" or "blaes" which is met with. The pit is widened out, and is generally sunk three or four feet below this point so that the water may not trouble those putting in the tubbing. The pumps must be kept well into the shaft, so that the workmen may get easily at the back of the crib for the purpose of wedging. In sinking past the place where the crib is to be laid, care must be taken to have the pit the exact size that it is intended to be, and no shots ought to be placed except in the center or within three feet of the sides, lest they shatter the strata near the crib seat. A scaffold is then placed across the pit so that the men may more conveniently cut the crib seat and wedge it securely. It is the main stay of the tubbing, and everything must be done with watchfulness and carefulness so that the work may be well done; this cannot be too strongly impressed upon all engaged upon it. The bottom and sides of the crib seat require to be cut water level and plumb, and this requires to be done with great caution. It is cut 3 inches wider than the breadth of the

crib, and this space requires to be cut all round to a center line, and perfectly plumb and water level. It is cut out first on the back and sole with picks, as near to the size as possible, and then adzed smooth to take out the pick marks. The adzing must be done until it is as smooth as glass, and all the pick holes taken out. There must be no hollows in it. If there should happen to be any faulty place the faulty place is cut out. The great importance of this will be at once seen, for there can be no repairs made upon the wedging crib afterwards, and if it is not water tight another crib seat must be cut out a few feet below and joined to the first. When the crib seat has been satisfactorily cut the wedging crib is laid upon it as follows:

First: Pieces of half-inch fir deal called sheathing, the full width of the crib, are placed endways to the pit, all round. Upon this the crib is laid, trained carefully by the center line, pieces of half-inch oak sheathing being placed at the ends of each of the segments. The crib so laid is half an inch wider in diameter than the pit, but the wedging brings it to the correct size. When it is placed in position, pieces of wood called gluts, made to the exact size to fit in between the back of the crib and the wall, are driven down to the full depth of the crib, two pieces in each segment to keep it in position. When this is done the space all round is filled with similar pieces driven close together.

The crib is now ready for wedging, but in order to prevent it from rising in front, props are put from the crib to the strata above. The first round of wedging is made with wooden wedges, 6 inches long by 2½ by 1-3rd inch, the front of the wedge towards the center of the pit, a hole having been first made with the wedging chisel for the wedge to be driven into. The wedging chisel is generally made 6 inches long and 2½ inches wide at the broad or chisel part. The wedges are driven carefully, so that they may reach as far in as possible, and if they do not go in their full length they are cut off with the chisel, level with the top of the crib. The wedging is carried regularly round, and continued until the wedges refuse to be driven in, and then chisels an inch wide and wedges to correspond are driven in until the wedges will scarcely enter. It usually takes eight or ten rounds of large wedges and two rounds of inch wedges to complete the wedging. The last course is a course of iron wedges driven in angleways, which makes the space between the back of the wedging crib and the sides of the shaft perfectly water-tight.

The wedging crib is now ready for the segments, which are placed in rings. Fir sheathing, the breadth of the segment and one-half inch, is laid on the top of the wedging crib. The segments are now laid on, pieces of sheathing being placed at the joints. The circle of segments is kept in its place by long wedges driven down between each segmemt and the wall. When the first circle has been fairly placed, the space behind the first round is filled up with Arden lime or other cement, so that if there are any leaks in the wedging crib the lime may assist in silting them up. Another range of sheathing is laid on and the next circle of segments is laid on, the vertical joints being broken like mason work, sheathing being put in the end joints as before, and tier after tier is put on until they are above the height to which the water will rise. After the whole has been put in and joined, the wedging of the segments is commenced. This is done with ordinary wooden wedges, 4½ by 1½ by 1-3rd, going regularly round from the bottom upwards, twice up and once down, till it is perfectly tight. Until the wedging is completed the water runs through the plug holes in each plate. After the wedging is completed the holes in each segment are plugged up, and the whole is perfectly tight. In some cases instead of the segments being carried up as far as the water will rise, a wedging crib is placed at some convenient point above the water-bearing strata, and the segments closed up on it. In this case the water is confined between the two wedging cribs and between the two beds of shale or water-resisting strata in which the wedging cribs are placed. This is called close-topped tubbing, and is by no means so simple as the others, but the process is the same. It is usual in close-topped tubbing to put on a valve so that any air may escape freely while it is filling. Wood is frequently used instead of iron,

but in all cases the wedging crib requires to be specially attended to.

Tubbing, as described, was put in at Allanshaw, near Hamilton. The shaft was 14 feet diameter, and reached the Ell coal at a depth of 118 fathoms. At a point about 60 fathoms from the surface a feeder of water 1000 gallons per minute was met with in a spongy sandstone. It was effectually tubbed back, very little more water was found below this point, and the pit was afterwards sunk without a pumping engine. The total cost of labor and wood for 8 fathoms of tubbing at Allanshaw was £177. It was put in by the manager, who had never seen tubbing put in before.

EXPLANATION OF A METHOD OF PREVENTING CORROSION OF IRON AND STEEL, AS APPLIED TO NAVAL AND MILITARY PURPOSES.

By Professor BARFF.

"Journal of the Royal United Service Institution."

I think it is desirable, before entering into a description of the processes which I have undertaken to explain to you this evening, that I should, for the benefit of those who are not acquainted with chemistry, go into the nature of the changes which iron undergoes when it is submitted to the action of oxygen gas. I feel this to be more important since my process has become somewhat generally known, and interested persons have applied to me to explain to them its nature and its various applications. I have found a very great difficulty in making those who are otherwise well instructed understand the process, from their ignorance of the chemical reactions which it involves, and of those, connected with iron itself, which it prevents. Many of you here present, I have no doubt, understand thoroughly all that I am now going to treat of, but there are also others who I most earnestly wish to make thoroughly comprehend this process, who have not got that preliminary knowledge, and who must have it to some degree, in order that they may be able to understand the principle of the process, and its applications to iron. I shall, therefore, take the liberty, Mr. Chairman, with your permission, of endeavouring to make my explanations more clear by the use of a few simple experimental illustrations.

Iron in perfectly dry air does not rust at all; that means to say that the oxygen of the air will not unite with it. I have here an illustration of this, for in this bottle is a piece of bright iron wire which has been placed there for some days. In the lower part of the bottle you will notice a thick liquid. It is called oil of vitriol, and it has the property of absorbing moisture, so that by it the moisture of the air in this bottle has been absorbed, and we speak of the air as being perfectly dry. You notice that the iron is not rusted at all. Now I have a similar piece of iron in a similar bottle, and this contains none of that liquid which is able to absorb moisture. The iron has been in the bottle for exactly the same length of time, and you notice that it is rusted, for the air in this bottle is moist; that is to say, it contains water-vapor in suspension, just as does the air in this room. Now I take another piece of bright iron wire, and I make it red-hot in the flame of this lamp, and you notice that it is covered with a black film, and this film is an oxide of iron, analogous to that which is formed in smithies, where hot iron is beaten into shape on the anvil. Around the base of an anvil in any blacksmith's shop you will notice a number of scales lying about, which persons are generally accustomed to consider as pieces of iron which fall from the iron when it is beaten. They are not iron, but oxide of iron. Now, in the first instance, the oxide is of a reddish color, and is known by the common name of iron-rust, and the other is black. Now, Gentlemen,

bear with me for one moment. I have here in this bottle a green solution. It is a solution of what is ordinarily known by the name of green vitriol. Now, green vitriol is a compound of another oxide of iron with sulphuric acid. Certain substances are able to take away the sulphuric acid from this vitriol, and this oxide of iron, which is insoluble in water, is thrown down as a precipitate. I need not tell you the names of these substances which have this particular property. It is simply enough for me to show you the result. I now add some of this colorless liquid to the green solution, and you see a dirty green substance is precipitated. I will throw this upon a plate, and it will begin to change color. It will pass from dirty green to yellow, of a more or less reddish hue. It is manifest that a change of some kind must take place in its composition, in order to produce this change of color, and the change is caused by the fact that the oxygen of the air has united with it, and has changed it from the lowest oxide of iron into the highest. The composition of the dirty green precipitate is as follows: 56 parts by weight of iron and 16 of oxygen, and when it becomes yellowish-red the composition of that body is twice 56 parts by weight of iron, and 3 times sixteen by weight of oxygen. That is to say, the iron has taken up half as much oxygen as it had before, and hence that oxide is called a sesqui-oxide. I have here in these two tubes some of this sesqui-oxide. In the one tube you will notice that the color is bright yellow, and in the other that it has approached more or less to a greenish hue. The tube in which this greenish substance is, contains a piece of metallic iron, for into both tubes the same yellow substance was originally placed mixed with water; the iron in the one tube has commenced taking away oxygen from the sesqui-oxide, and is gradually reducing it to the state of the lower oxide. From this experiment you will perceive that the lower oxide of iron, when it is in the moist state exposed to air, takes up more oxygen, and that in the moist state, when acted upon with iron, it gives up oxygen to the iron. You will now be prepared I hope fully to understand the process which takes place when iron rusts. Moisture must be present, then the oxygen of the air unites with some of the iron forming the lower oxide, the same as that which I have just precipitated from the solution of green vitriol, and this, when exposed to air, becomes the higher oxide, and this higher oxide in the presence of moisture gives up some of its oxygen to the metallic iron, becoming the lower oxide again in part, and this absorbs more oxygen from the air, and so the process goes on continually until the iron gets oxidized through its substance, or, as we in common parlance say, rusts away.

To return now to the oxidation of iron when heat is applied. If moisture be absent, only the black oxide is formed, and this black oxide is incapable of giving up its oxygen to iron, or of, under any circumstance, taking more oxygen from the air.

I have arranged some experiments to illustrate this I hope satisfactorily to you all. In a hard glass tube, connected with an apparatus consisting of a flask in which steam is generated, and which hard glass tube is heated throughout its length in a gas furnace, I have placed some iron filings and iron wire. I will pass the steam through this tube, and will collect in a bottle the hydrogen gas which is given off. You will notice that the iron filings and the iron wire have both assumed a dark-grey color. This is owing to the conversion of their surfaces into the black oxide of iron, and the hydrogen gas you will see presently burn with its characteristic non-luminous flame. Now, if this iron wire be rubbed with the finger a portion of the black oxide can be removed, and if both wire and filings be exposed to moist air they will rust where the oxidation is not complete. In this bottle iron filings and wire, which were similarly treated a few days ago, have since been exposed to the air, and you will notice that they have rusted in part. I will now, instead of allowing the steam to pass directly into the glass tube, cause it to circulate through a coil of pipe which is placed in the center of this little charcoal furnace, which is now perfectly red-hot. In its passage the steam will become dry or superheated. I will now let this steam pass into this other tube with which I have replaced the former one, which contains pieces of bright iron wire, and

likewise some iron filings. The superheated steam will form on the surface of the wire a coherent and adherent coating, which will not rust on exposure to air. I don't mean to say that in the short space of time this iron has been exposed an absolutely perfect coating will be formed, for in practice iron to be rendered non-corrosive is usually exposed to the action of superheated steam from four to ten hours. In this case hydrogen gas is given off as in the former.

It is very interesting to me to know that several chemists, skilled in the application of that science to the arts, have endeavored to effect, without success, what I, by a lucky chance, have been fortunate enough to accomplish. These gentlemen have related to me their experiments made, in some cases ten and in others twelve years ago, with a view to convert the surface of metallic iron into the black oxide, so as to prevent corrosion, and they have all told me that they failed at one particular part of the process, for they were not able to get a hard and coherent surface. It was my good fortune to make an observation in one of my experiments, after many, many failures, which opened my eyes to the reasons why all my previous experiments had failed, and now tells me how it was that these gentlemen failed before me. My early experiments were made in an iron tube, about ten inches long by two inches diameter, the two ends of which were closed with iron caps, and into it, at each end, an iron pipe was fastened, the one for the passage in of steam and the other for the outlet of hydrogen. Into this small chamber pieces of iron were put, and the chamber itself was placed in an ordinary furnace. Steam was generated in a glass flask, and was allowed to pass into it for a short time, the iron chamber being heated to a red heat: I found that the iron was coated with black oxide, that hydrogen gas escaped from the exit tube, for I collected and burnt it. The black oxide was more or less adherent to the surface of the iron. Sometimes it was so pulverulent that it could be dusted off. At others it seemed more firm and coherent, but on exposure to air, the iron rusted and the black oxide was thrown off in powder or in flakes. On one occasion, on taking out a piece of iron, after it had been heated, from the iron chamber, I noticed that at one part there was a brownish-red tint upon it. This immediately gave me the idea that some of the red oxide of iron was produced on its surface, and that this was, in some way or other, mixed with the black oxide. The idea immediately struck me that, owing to the presence of moisture in the steam, some red oxide was first formed, that it was afterwards reduced to metallic iron by the hydrogen set free on the further action of iron on the steam, and that this reduced iron was eventually converted by the steam into the black or the magnetic oxide. Further observation tended to confirm and, I think, eventually to prove that this surmise of mine was correct. For I immediately had a coil of iron pipe made and attached to the iron chamber, between it and the ingress tube, and this coil was so constructed that it could be put along with the chamber into the furnace, and so be heated to a high temperature. The steam therefore passed slowly through the red or white hot coil of iron pipe previously to its coming in contact with the iron to be acted upon, and nearly the first experiment that I made with this new apparatus showed me that a hard coherent coating adherent to the iron could be produced. From that time to the present, the only difficulties which have attended the carrying out of this process have been of a mechanical nature, and have been step by step overcome, so that now, with almost absolute certainty, we can charge one of our furnaces and bring out all the specimens with a satisfactory coating. Sometimes we may have a few failures, and these all go to prove the fact that my theory, already stated, must be true. For, if the steam be turned into the chamber when it is not sufficiently hot to keep it in the state of dry steam, some of it gets condensed, water-vapor is formed, and this produces a result similar to that which I have explained to you as happening in our earlier investigations. I have to render thanks to my friend, Mr. Hugh Smith, for the help he has given me in carrying out this part of the application of my process. He has superintended the muffle in the treatment of all the experiments on the

table. I have already mentioned to and shown you that the black oxide of iron is formed when iron is heated in atmospheric air; but, when it is so formed, it never adheres completely to the surface on which it is produced, and always on exposure to moisture comes off, a coating of red rust being formed around and beneath it. Therefore, we found it essential and necessary to expel all atmospheric air from our heating-chamber before we allowed the entrance of superheated steam.

I may say that there are two conditions absolutely necessary to success. The one is that no atmospheric air be present, and the other, that the steam be perfectly dry. The iron before being submitted to the action of dry steam must be perfectly clean, that is, it must have no spots of red rust upon it, for if it have, the results which I have previously explained to you will be produced in these particular spots, and after exposure to air rust will appear upon them. But you will see from the specimen to which I now call your attention, that this rust is perfectly circumscribed and does not extend laterally, nor is it formed under the coating of the black oxide. So that if some large article, such, for instance, as a girder, were treated, and if many spots rusted after a time, owing to the causes which I have just explained, the strength of the girder would not in any way be impaired, as the rust would be perfectly localized and would not spread. This bar of iron was treated all over; with some difficulty I rasped off a portion of its surface, and the whole was exposed for a very considerable time through the late heavy rains on a lawn. You will perceive that the half from which the black coating has been removed has rusted completely, and that the rust has eaten its way a considerable depth into the iron, but the line of demarcation between the part not rusted and the rusty part is as well marked and defined as it was when the iron was first exposed. There is also in the black part of the coating a small spot of red crust, which appeared shortly after its exposure, which has not in the slightest degree enlarged. That the acid-vapors of a laboratory have not any action on this coating of magnetic oxide is proved by these specimens before you, which for several months were kept in my laboratory where ten or twelve students are continually at work, and for six weeks of that time these pieces of iron were watered daily, except on Sundays, in order that the moisture might absorb the acid-vapors of the laboratory, and so corrode, if they could do so, the surface of the iron. You will notice that it is perfectly unchanged; but the places where the iron is exposed, through the intentional fracture of the iron, are all covered with red rust. Most of the specimens before you have been exposed for a longer or shorter time to the rain and dews of night, and I think you will see in all cases they have resisted more or less completely the action of the moist air. I need not take up your time longer by describing all the specimens before you, or by entering more fully into an explanation of the process. I believe I have already done it fully, and I believe in a way so simple that everyone, even the most unskilled in scientific matters, will be able to understand it.

Now, as regards its application to purposes in which you are all deeply interested. We will speak first about steam boilers and steam ships. Here is a piece of boiler plate, which after it was taken out of the furnace was rubbed with steel wire cloth and emery paper, which has produced this sort of gloss upon it. It has been some time in the sink of the laboratory, and is, as you will see, perfectly free from rust. The black coating is firmly adherent to the surfaces. Suppose a boiler plate or an armor plate to have its holes drilled and to be oxidized, and suppose also that the rivets are oxidized as well, then when the plates are riveted together, the rivets being heated till they become soft, a proper pressure is brought to bear upon them, and this pressure may possibly interfere with the coating on the head of the rivets. I don't see well how it can interfere with it upon any other part of them. Next comes the caulking: and here, no doubt the tools used would go through some of the black oxide and expose small portions of metallic iron, and this might rust. However, I must here mention that in one specimen before you, which I exhibited at the Society of Arts, a notch has been cut, and this was done by some

one at the meeting in order to test its hardness. Now, it has been exposed ever since to the action of moisture, and this notch as you will see, is not rusted at all, so that I fancy the iron is rendered non-rustable to a depth below the black surface, and this view is confirmed by the fact that almost every piece of iron from which I have removed the black surface only, without going into the iron below, has never rusted to any appreciable extent, and that the rust which forms upon it is not of the deep color of ordinary rust, but is yellow, like certain well known hydrates of the sesqui-oxide of iron, and that, moreover, this yellow, substance can be wiped off, leaving the iron perfectly clean. This cannot be done to any piece of metal on which has been formed the ordinary iron rust. At present I am not in a position to speak with certainty, resulting, from experiment, as to whether this process can be applied to ships or boilers, so as to prevent rust in every part. But even suppose we cannot get over the difficulty resulting from the disturbance of the coat of oxide on the rivet-heads, it seems to me that very much will be gained by our being able to render the plates non-rustible, for it is manifest that it would take a very long time for iron rust to eat vertically into the head of a rivet. But I am sanguine enough to believe that this difficulty, which is not nearly so great as others which have been overcome in the perfecting of this process, will be vanquished likewise. One of the specimens before you has been placed in salt and kept in a moist atmosphere where the salt was alternately dry and wet for a very long time, and you will preceive that this black coating has been in no way affected. I do not, therefore, think that there is any fear of sea-water decomposing it. This small sample of black oxide was taken from the sea-shore and it has never rusted. I think that we have been able to prove that gun-barrels can be treated with it without injuriously affecting their surface. You will see before you several specimens, and of the effect produced upon them you will be better judges than I am. Several officers in the Navy have mentioned other applications which will be of inestimable benefit to various portions in the structure and furniture of ships. But here, again, Gentlemen, I need not take up your time by detailing them; for now you know the process thoroughly, you will be the best judges as to where it can be efficiently employed; for to all the bright iron and steel work in use among soldiers, whether helmets, swords, or scabbards, it may be applied with great advantage. For, as far as I know, it does not interfere with the strength or tenacity of the metal, and it most certainly hardens its surface. For stores of iron cannon balls and shells, its application will be of very great advantage. An officer in the American Army told me the other day that the rusting of these materials of war is a source of considerable inconvenience. It is rather for you, Gentlemen, to point out to me the ways in which it can be made of use to you, than for me to mention them to you, and then I conceive it is my business to practically carry out your views, and see whether its application is admissible. Some time ago Mr. Perkins read, as I hear, a most interesting paper here upon his boiler-tubes, in which he mentioned the strange results which had arisen from the action of water upon them at very high temperatures, and therefore under very considerable pressure. I am sorry to say that at present I am not able to throw that light upon the subject which I could wish to do, for a series of experiments which I am performing with specimens which he has given me are not yet completed. If by the time this paper is read I have completed them, I will write an account, which shall be appended to it. And thanking you very much for the kind attention you have given me, I shall now be happy to hear any remarks which you may desire to make, and to answer to the best of my power any question you may ask me.

For experimentally illustrating the composition of light Mr. Wm. Terrill arranges seven lanterns, with glass slides stained to imitate the different colors of the spectrum. By turning the lanterns so that the projected circles overlap, a circle of white light is produced. Interesting experiments with complementary colors may be performed in the same way.

DYNAMO-ELECTRIC APPARATUS.

From "Engineering."

It cannot but force itself upon the mind of any thinking person that among all the forces of nature, so many of which have already been called into use in the ever onward march of industrial progress, electricity is destined to take a very prominent place in the immediate future. Indeed, there are not a few indications to warrant the belief that the coming half century will be characterized in the world's history as an electrical age, just in the same way as previous periods have left their mark according to their several characteristics being referred to as "Golden Age," "the Age of Literature," "the Iron Age," and others to which special characteristics belong.

A retrospect of the last twenty, or even of the last ten, years is sufficient to show that electricity and its applications have had an important and rapidly increasing share in the inventions and the industries of the world. Electric telegraphy has been reduced to an exact science, and has given rise to a new and distinct profession—that of the telegraph engineer—besides giving employment to thousands in the manufacture of telegraph lines of submarine cables, and of signaling instruments. Another branch of it has rendered possible the safe and rapid facilities of transit which railway communication affords, for it would be idle to suppose that the railway system could ever have developed itself into anything like the power that it is had it not been aided by the electric telegraph.

Again the arts of electro-plating and of electro-typing have become large and important branches of industry, especially in this country and in France, the latter by the cheap and rapid facilities it affords for the reproduction of engravings having already revolutionized the production of illustrations for an important branch of literature.

The great novelty of the day, the telephone, has done much in a short time to draw popular attention to some of the most interesting capabilities of electricity, and has prepared the public mind to a very great extent for believing almost anything of electricity and for taking up inventions and industries which are based upon electrical phenomena.

As long, however, as the only available sources of electricity were voltaic batteries, consuming as they did so expensive a fuel as metallic zinc, the applications upon a large scale of electrical action were very limited on account of its cost. The discovery by Faraday of magneto-electricity and the various magneto-electric machines which arose therefrom, appeared to open up a field in which cheap electricity might be sought, and by which several experiments hitherto confined to the laboratory might become developed into branches of industry. The machines of Holmes and of the Société l'Alliance were the first applications upon a large scale of Faraday's discovery, and the illumination of several of the important lighthouses on the coasts of England and France by the electric light generated by the Holmes machine and by its French modification, the Alliance machine, gave a fresh impetus to electrical progress.

In both these machines, however, the current was induced from permanent steel magnets which could not retain sufficient magnetism to maintain a magnetic field of sufficient intensity to induce powerful electrical currents in the coiled armatures. To compensate for this deficiency, the number of magnets and of armatures had to be multiplied, and the size of the machines as well; their cost for driving (to say nothing of prime cost) was thus very great. The Siemens cylindrical armature utilized to the best advantage the inductive action of the magnets. As long, however, as the induction of electrical currents was produced by the action of permanent magnets, an increase in the size of a machine did not produce a proportional increase of results, and as it was found that iron takes an appreciable time to be magnetized and to be demagnetized, there was also a limit to the speed at which a machine could be driven so as to produce satisfactory results.

Mr. Wilde, by employing electro-magnets (excited by a smaller magneto-electric machine) for inducing the currents in a Siemens armature, supplied the connecting link between the early magneto-electric and the modern powerful dynamo machines, which depend for their action upon what is called the action and reaction principle of magnetization, which has been rendered familiar to the readers of this journal by a recent correspondence carried on in these columns relative to the question of priority of its discovery. It is the employment of this mutual action that distinguishes dynamo-electric from magneto-electric machines, and it carries with it this overwhelming advantage that the power of a dynamo machine increases in proportion to its size, to which practically there is no limit.

There are at the present time but two dynamo-electric machines of sufficient development to be considered in this article, viz., the Gramme and the Siemens machines, both of which have been described in these columns. The former has now become a very formidable rival in France to the Alliance machines for the production of the electric light, and has recently been employed during the building of the Paris Exhibition for enabling the building operations to be carried on at night.

The Siemens machine has, however, carried off the palm in all competitive trials with the Gramme, and in an article in our last volume we embodied the results of a long series of most interesting experiments made for the Corporation of the Trinity House by Dr. Tyndall and Mr. J. N. Douglass, for ascertaining the comparative merits of the two machines. From these experiments (a detailed account of which was given in the reports of Dr. Tyndall and of Mr. Douglass which we printed in the same volume) it was proved that to produce the same light a Siemens machine would weigh 3 cwt. as against 25 cwt. for Gramme, and would require to drive it but 3.3 horse power against 5.5 for Gramme, giving a proportion of light produced per horse power of 2080 for Siemens to 1257 for Gramme. Thus one Gramme machine would weigh more than eight Siemens machines of equal power, its cost of driving would be nearly double, and in addition to these points in favor of the Siemens machine, the prime cost of the machine is as 100 for Siemens to 320 for Gramme, that is to say that three Siemens machines cost less than one Gramme machine of equal illuminating power. We are told in a letter from Mr. Charles Ball, which appeared in our issue of the 2nd of November last, that the Gramme machine has been improved since the Trinity House experiments were made, but as that improved machine has never been subjected to any recognized competitive trial against the Siemens machine, the necessary data are wanting for estimating the relative merits of the two machines.

Whatever form, however, will ultimately prevail, it is to dynamo-electric apparatus that we must look for bringing about that great future for electricity which has often been predicted in these columns, and we are glad to see that the importance of the subject is being recognized at head-quarters, and we must congratulate the Institution of Civil Engineers upon the valuable paper upon dynamo-electric apparatus by Dr. Paget Higgs and Mr. Brittle, which was read at the meeting last week, and which gave rise to a very interesting discussion which is not yet closed. In the paper, of which we published a short abstract in our last issue, the authors, after reviewing the history of the subject, gave a full description of the latest improvements of the Siemens machine, and of the special apparatus designed by Messrs. Siemens for the new electric lights at the Lizard lighthouses.

In connection with electric illumination it is not possible to overrate the importance of the lamp or regulator, by which the carbons are maintained at such a distance apart as to insure a steady light. Hitherto it has always been a weak point in the application of electricity to illumination purposes that the light produced was of an unsteady and flickering nature. This fluctuation might be produced by one or more of three causes: (1) variations in the speed of the machine, whereby the electro-motive force was rendered inconstant; (2) defects in construction of the regulator; and (3) impurities and want of homogeneity in the carbon points. The first of these is a simple mechanical question

and can be remedied by an efficient governor to the engine. The second has been got over in the lamp of Messrs. Siemens, which, while quickly adapting itself to variations in the current is exceedingly simple and not liable to become deranged as are the highly complicated clockwork regulators of Serrin, Foucault, Duboscq, and others. Uniformity in carbons can only be secured by careful selection, but during the last few years the manufacture of carbons for electrical purposes has greatly improved, and only wants the stimulus of a large demand to induce manufacturers to pay the attention to it that the importance of the subject deserves. The presence of small granules of silica seems to be the most deleterious, causing portions of the carbon points to split off often with a slight explosion. The plan of electro-plating the carbons with a thin film of metallic copper is one which recommends itself for several reasons. It gives to the carbon sticks a uniform conductivity and diminishes their resistance, by which they are kept from being heated by the passage of the current, and by encasing them in a copper sheath it reduces to a minimum their chances of splitting, besides making them less fragile to handle, and the film of copper is so thin as not to affect the color of the light by its own vaporization or to produce noxious sublimates in the atmosphere in which the lamp is burning.

If, while a dynamo-electric machine is running, its terminals be connected together, its external circuit being thereby closed, it will be found that a great resistance is offered to the rotation of the machine; the closing of the external circuit has an effect upon the engine similar to that produced by suddenly putting a heavy cut upon a lathe, and were it not provided with an efficient governor, the engine would, to a certain extent, be pulled up. Similarly if, while the machine is running, the external circuit be broken, work is taken off the machine, and without a governor the engine would "run away." From this it will be apparent that if the lamp were suddenly put out, the load would be taken off the engine, and injury might accrue from the suddenly increased speed of rotation. To remedy this a self-acting shunt is interposed between the machine and the lamp.

In the paper read before the Institution of Civil Engineers some very interesting comparisons were given between the cost of lighting by electricity and of lighting by gas, the proportions of which vary greatly in different places, being dependent upon the cost of gas at the particular place selected, and upon the kind of motive power employed to drive the machines. It appears, however, that for the illumination of large areas the cost of the electric light is about one-fourth or one-fifth of that of lighting by gas. At the works of Messrs. Siemens Brothers it has been found that there the economy is as two to one in favor of the electric light over gas, with the further advantage that the lighting is perfect, and is not attended with the inconvenience that gas is subject to, of being obscured by steam or fog.

We cannot doubt that the time will come when central stations for distributing electric power will be established in all our large towns for illumination purposes, for the transmission of power to a distance, and for other manufacturing and industrial purposes. There are abundant data by which it can be shown that coal can be more economically used for the illumination of a town by being consumed in a steam engine, which is employed to drive a set of dynamo-electric machines, than by being converted into gas and conveyed by pipes all over the district to be lighted. Again, for the transmission of power from a central station, where strict economy can be practiced, aided by very perfect steam engines, economical results would be obtained, for the great waste of energy caused by a number of small and badly constructed steam engines, would more than cover the extra cost of transmission by means of electricity, from a center where economy was practiced upon sound scientific principles.

A method of illuminating large halls was exhibited to the meeting during the discussion on the paper above referred to. This arrangement, which was first suggested to Dr. Siemens by the Duke of Sutherland, consists in projecting the rays from an electric lamp by means of a concave reflector vertically upwards

upon a white ceiling, or, as was done at the Institution, upon a large white sheet, stretched horizontally across the roof. The effect was as near to perfection as illumination could be: the reflector being deep enough to screen direct rays of the lamp from the eyes of the audience there was no unpleasant glare, and the room was flooded with a soft, purely white, and at the same time most brilliant light, so perfectly distributed that it was impossible to cast a shadow upon a sheet of paper by an object placed twelve inches off. The most striking effect, however, was produced by the electric light being stopped, leaving the three powerful "sunlights" doing their work alone.

The effect was as if the whole room was suddenly enveloped in a thick yellow fog, and it was difficult to believe that the illumination was the same as what appeared so brilliant before the electric light was shown.

PROGRESS OF TELEGRAPH ENGINEERING.*

By Dr. C. W. SIEMENS.

From "Journal of the Society of Arts."

In reviewing the progress made in telegraph engineering during the last few years, I propose to notice in the first instance the subject of duplex and quadruplex telegraphy, which has recently much occupied the attention of the telegraph engineer. Duplex telegraphy has been known and practiced to a very limited extent since 1854 (?) when it was first announced by C. A. Nystrom, of Oreboro, Sweden, and by Dr. Gintl, of Vienna, and carried out practically by Frischen and Dr. Werner Siemens. Although quite successful in some of the applications made at that time in Germany, in Holland (between Amsterdam and Rotterdam), and in this country, under my own superintendence, between Manchester and Bowden, telegraphy itself had not advanced sufficiently to call for an application of this invention upon a more extended scale, and it has only met with favor on the part of telegraph administrators since its reintroduction to public notice by Mr. Stearn, of Boston, in 1872, who improved, however, upon the original arrangement by balancing the discharge from the line by the discharge from an arrangement of condensers. Another important advance in duplex telegraphy has been made by Mr. Louis Schwendler, who, by the application of an improved Wheatstone bridge arrangement has produced the means of readily adjusting the effect of the neutralizing current during the working of the instrument, and has carried duplex telegraphy into effect with great advantage upon the long lines of India, with which he is connected.

The quadruplex telegraph, which may be considered to have been theoretically introduced by Dr. Stark of Vienna in 1855, and contemporaneously by Dr. Boscha of Leyden, has been developed by Mr. Edison of New Jersey, United States, and has been for some time established upon the line between New York and Boston, under the superintendence of Mr. Prescott, the engineer of the Western Union Line. In this system the principle of duplex telegraphy is combined with the equally well-known system of producing different effects by currents differing in strength.

Our attention is next arrested by the great novelty of the day, the telephone. This remarkable instrument owes its origin to the labors of several inventors. In the year 1859 the late Sir Charles Wheatstone devised an arrangement by which the sounds of a reed or tuning-fork, or a combination of them, could be conveyed to a distance by means of an electric circuit, including at both stations a powerful electro-magnet. In striking any one of the tuning forks differential currents were set up which caused the vibration of the corresponding tuning fork at the distant station, and thus com-

*. Presidential Address delivered at the Annual Meeting of the Society of Telegraph Engineers, January 23d, 1878.

municated the original sound. In 1861 Reiss enlarged upon this ingenious suggestion in attempting to convey the varying vibrations of a diaphragm agitated by atmospheric sound-waves. This instrument transmitted currents only of equal intensity, and produced therefore sounds of equal calibre, distinguishable only by their periods. Mr. Edison, by establishing contacts through the medium of powdered plumbago, has succeeded in transmitting galvanic currents varying in intensity with the amount of vibration of the diaphragm. As another step towards the accomplishment of the perfect transmission of sound, I should mention also the logograph, or recorder of the human voice, which Mr. William Henry Barlow, F.R.S., a member of our society, communicated in a paper to the Royal Society, on the 23d February, 1874.

The beautifully simple instrument of Professor Graham Bell, of Cambridge, United States, must be regarded as a vast step in advance of all previous attempts in the same direction. In making the diaphragm of iron, and having recourse to Faraday's great discovery of magneto-induction, Mr. Bell has been able to dispense with the complication of electrical contacts and batteries, and to cause the vibrations of the diaphragm imparted by the voice to be accurately represented in strength and duration by electrical currents, thus producing the marvelous results of setting up analogous vibrations in the diaphragm of the receiving instrument, which, though weaker than the vibrations imparted to the transmitting diaphragm, so closely resemble them as to repeat the quality of voice which causes the original vibrations. The currents transmitted are so minute as to escape observation by the most delicate galvanometer, as the magnetic needle, however light, must be too sluggish to be moved visibly by such quick impulses, and it requires an electro-dynamometer of exceeding sensitiveness to bring them into evidence. The rapidity with which these reversing currents follow each other can be accurately determined in transmitting the sound of a high-pitched tuning fork, and Mr. Köntgen concludes, from experiments he has made in this direction that not less than 24,000 currents can be transmitted in one second. The system of suspended line-wires now generally in use is open to many grave objections. The mutual induction between parallel line-wires, and the leakage from one wire to another through the supporting poles are a permanent source of trouble in working telegraph instruments. Again, it happens that not unfrequently suspended line-wires are thrown down, causing the almost entire cessation of telegraphic communication for days in the event of a great gale or snow-storm. The remedy for these interruptions is undoubtedly the underground line-wire system. This was first tried in Germany upon an extended scale in 1848-9, but was given up in favor of the suspended line in consequence of the want of experience in manufacture and imperfect protection afforded to the gutta-percha-covered copper wire. Since then it has been largely used in this country. The German Telegraph Administration, under the able direction of Dr. Stephan, has within the last year or two again resorted to the application of the underground conductor for long lines. A represesentative cable of what it was intended to lay was put down in 1876 between Berlin and Halle, a distance of 120 English statute miles. The success of this line induced his Government to lay down last year multiple cables between Berlin and Cologne, and Berlin, Hamburg, and Kiel, an aggregate distance of 600 miles, while further extensions are in course of execution.

In submarine telegraphy no startling feat of novelty can be reported, although steady progress has recently been made in improving the manufacture of the insulated conductor, in the attainment of an increased rate of transmission through long distances, in the outer protection given to the insulated conductor, and in the vessels and other appliances employed for submerging and repairing deep-sea cables. The conductor almost universally adopted in the construction of submarine cables has been a strand of seven copper wires, covered with three thicknesses of gutta-percha, with intervening layers of a fusible resinous compound.

In the case of the Direct United States Telegraph Company's Cable, the conductor consists of one large central wire of 0.090 inches diameter, surrounded by

eleven small copper wires of 0.035 inches diameter.

Although this country has from the first taken a prominent part in the invention and development of the electric telegraph, and is still the seat of oceanic telegraphic enterprise, almost to the exclusion of other countries, it has lately been asserted that other countries, and especially the United States, are now taking the lead in telegraphic improvement, and it behoves us to inquire whether such an allegation is founded on fact, and, if so, whether it is attributable to indolence on our part or to circumstances beyond our control. It cannot be denied that the more startling innovations of recent days have chiefly emanated from the United States, the only civilized country in which, as it happens, internal telegraph communication is still in the hands of private companies. Is it, it may be asked, this open competition which has stimulated the American inventor to bring forth duplex and quadruplex telegraphy, the telephone, and other innovations? I incline to the belief that the open competition for public favor does act as a powerful stimulant to invention in the United States, a stimulant which was equally active in this country in producing a variety of novel instruments, at the time prior to the purchase of the telegraphs by the Government. In frankly giving expression to this opinion, I do not mean to call in question the wisdom of the policy which dictated the purchase, on public grounds, of the telegraphs by Government. Through it we have obtained a uniform and moderate tariff, an extension of the telegraph system to minor stations (although the number of stations open in this country does not yet exceed that provided in the United States, being in the one case a station for every 5,607, and in the other for every 5,494 inhabitants), and a better guarantee for the secrecy of messages.

It is a question worthy of consideration whether the Acts of Parliament of 1868–9, by which the Government Department of Telegraphs was created in this country, do not go beyond the limits necessary to insure a well-regulated public service in taking the construction, as well as the working of the lines, out of the hands of public enterprise. They give, for instance, to the department the faculty of purchasing letters patent, whereby an interest is created in favor of particular instruments, to the prejudice of others of perhaps equal merit, and such a course is by no means calculated to stimulate invention.

The erection of lines for local and private purposes is an important branch of telegraphy which I submit should have remained entirely outside the scope of a public department, in order that competition might have a free opportunity of developing such applications, as is the case in the United States, where private and circular telegraphy is undoubtedly in advance of other countries. Great improvements have indeed been recently made by the Postal Telegraph Department in the rate of working of Wheatstone's automatic circuits, and in the employment of fast-speed translators or repeaters, as is proved by the following data, for which I am indebted to our vice-president, Mr. W. H. Preece. It has been found that the insertion of one of the new fast-speed translators in Dublin has more than doubled the rate of working between London and Cork, and the insertion of one of these relays in Anglesea has improved the rate of working between London and Dublin about fifty per cent. As an indication of the rate at which messages can be transmitted, it appears that the Queen's Speech, containing 801 words, was sent to Leicester in 4 minutes 28 seconds, being at the rate of 179 words per minute. The quickest rate at which it was sent by key was between London and Reading, where it occupied 17 minutes, or at the very high speed of 47.1 words per minute. It is, perhaps, interesting to remark that on the first night of the session over 420,000 words were actually transmitted from the central station, and over 1,000,000 words were delivered in different parts of the country.

The quadruplex system of telegraphy continues to be worked with very satisfactory results between London and Liverpool, and it has quite quadrupled the power of the one wire to carry messages. The highest number of messages transmitted in one hour has been 232; about 200 per hour have frequently been

sent. The system of duplexing Wheatstone automatic circuits is gradually extending, and on the Leicester wire which carried the Queen's Speech, at the rate named, messages were being transmitted in the opposite direction by the duplex arrangement at the same time. In submarine telegraphy ample scope still exists, as I have endeavored to show, for the ingenuity and enterprise of the telegraph engineer; but here again the free exercise of these faculties is threatened, not by legislative action, but by a powerful financial combination. It is intended by this combination to merge the interests of all oceanic and international lines and the construction of new lines into one interest.

Electricity has hitherto rendered service as the swift agency by which our thoughts are flashed to great distances, but it is gradually asserting its rights also as a means of accomplishing results where the exertion of quantitative effects are required. Much has been said about the application of electricity for producing light, and the French Company Alliance, as well as the Gramme Company, have it is known for some years been establishing magneto-electric apparatus to illuminate the lighthouses upon the French coast, and for galvanoplastic purposes. By an ingenious combination of two magneto-electric machines, with Siemens armatures, Mr. Wilde, of Manchester, succeeded in greatly augmenting the effects produced by purely mechanical means, but the greatest impulse in this direction was given in 1866-67 by the introduction of the dynamo-electrical principle, which enables us to accumulate the current active in the electric circuit to the utmost extent permissible by the conductive capacity of the wire employed. Dr. Tyndall and Mr. Douglas, chief engineer to the Trinity Board, in reporting lately to the Elder Brethren upon the power of these machines and their applicability to lighthouses, give a table showing that a machine weighing not more than 3 cwt. is capable of producing a light equal to 1,250-candle power per horse-power expenditure of mechanical energy. Assuming that each horse-power is maintained with an expenditure of 3 lbs. of coal per hour (which is an excessive estimate), it would appear that 1 lb. of coal suffices to maintain a light equal to 417½ normal candles for one hour. The same amount of light would be produced by 139 cubic feet of gas of 18-candle power, for the production of which 30 lbs. of coal are consumed. Assuming that of this quantity, after heating the retorts, &c., 50 per cent. is returned in the form of gas-coke, there remains a net expenditure of 15 lbs. of coal in the case of gas-lighting to produce the effect of 1 lb. of fuel expended in electric lighting, or a ratio of 15 to 1 in favor of the latter. Add to the advantages of cheapness in maintenance, and of a reduced capital expenditure in favor of the electric light, those of its great superiority in quality and its freedom from the deleterious effects of gas in heating and polluting the atmosphere in which it burns, and it seems not improbable that it will supersede before long its competitor in many of its applications. For lighthouses, for military purposes, and for the illumination of large works and public buildings, the electric light has already made steady progress, while for domestic applications the electric candle proposed by Jablikoff, or modifications of the same, are likely to solve the difficulty of moderating and distributing the intense light produced by the ordinary electric lamp.

The dynamo-electric machine has also been applied with considerable success to metallurgical processes, such as the precipitation of copper in what is termed the wet process of smelting. The effect of 1 horse-power expended in driving a dynamo-electric machine of suitable construction is to precipitate 1120 lbs. of copper per twenty-four hours, equivalent to an expenditure of 72 lbs. of coal, taking a consumption of 3 lbs. of coal per horse-power per hour. Electrolytic action for the separation of metals need not be confined, however, to aqueous solutions, but will take perhaps an equally important development for the separation in a state of fusion of the lighter metals, such as aluminium, calcium, and of some of the rarer metals, such as potassium, sodium, &c., from their compounds. Enough has been shown by Professor Himly, of Kiel, and others, to prove what can be done in this direction. In an inaugural address which I had occasion to deliver to the

Iron and Steel Institute, a twelvemonth ago, I called attention to another application of the dynamo-electric current, that of conveying mechanical power, especially the power of such natural sources as waterfalls, to distant places, where such power may find useful application. Experiments have since been made with a view to ascertain the percentage of power that may thus be utilized at a distance, and the results of these experiments are decidedly favorable for such an application of the electrical conductor. A small machine, weighing 3 cwt., and entirely self-contained, was found to exert 2.3 horse-power as measured by Prony's brake, with an expenditure of 5 horse-power at the other end of the electric conductor, thus proving that above 40 per cent. of the power expended at the distant place may be recovered; the 60 per cent. lost in transmission includes the friction of both the dynamo-electric and electro-motive engines, the resistance of the conductor, and the loss of power sustained in effecting the double conversion.

Without considering at present the utilization of natural forces, let us take the case of simply distributing the power of a steam-engine of say 100 horse-power to twenty stations, within a circle of a diameter, for the production of both light and power. The power of 100 horses can be produced with an expenditure of 250 lbs. of coal per hour, if the engine is constructed upon economical principles, or of

$$\frac{250}{20}=12.5 \text{ lbs.}$$

per station. In the case of the current being utilized for the production of light

$$2.3 \times 1200=2760,$$

or, say, 2,000 candle power, are producible at the station, whereas, if power is desired, 2.3 horse-power may be obtained, in both cases with the expenditure of 12.5 lbs. of coal, representing a penny an hour for cost of fuel, taken at 15s. a ton. The size of the conductor necessary to convey the effect produced at each station need not exceed half an inch in external diameter, and its cost of establishment and maintenance would be mall as compared with that of gas or water pipes for the conveyance of the same amount of power.

Electricity, which in the days of Franklin, Galvani, Volta, and Le Sage, was regarded as an ingenious plaything for speculative minds, and did not advance materially from that position in the time of Oersted and Ampère, of Gauss and Weber, and not indeed until the noonday of our immortal Faraday, has, in our own times, grown to be the swift messenger by which our thoughts can be flashed either overland or through the depths of the sea to distances circumscribed only by terrestrial limits. It is known to be capable of transmitting, not only language expressed in conventional cypher, but facsimile copies of our drawings and hand writing, and at the present day even the sounds of our voices, and of resuscitating the same from mechanical records long after the speaker has passed away. In the arts it has already played an important part through the creation by Jacobi of the galvano-plastic process, and in further extension of the same principle it is rapidly becoming an important agent in the carrying out of metallurgical processes upon a large scale. It has now appeared as the formidable rival of gas and oil for the production of light, and, unlike those inferior agents, it asserts its higher nature in rivalling solar light for the production of photographic images; and, finally, it enters the ranks as a rival of the steam-engine for the transmission and utilization of mechanical power. Who could doubt, under these circumstances, that there remains an ample field for the exercise of the ingenuity and enterprise of the members of that society I have just had the honor of addressing?

THE prizes of the Paris Academy of Sciences have been recently awarded. Practical engineering has secured some of the important awards. In mechanics the Poncelet prize was awarded to M. Laguerre for his mathematical works; the Montyon prize to M. Caspari, for his work on chronometers; the Phumey prize to M. Freminville, for his improvements in steam engines; the Fourneyron prize to M. Mallet, for his tramway engine.

—*The Engineer.*

ON THE EFFECTS OF PHOSPHORUS AND MANGANESE ON THE MECHANICAL PROPERTIES OF STEEL.

By M. EUVERTE.

From "Bulletin de la Société de l'Industrie minérale," Abstracts published for the Institution of Civil Engineers.

In the year 1874, the Author made a communication to the Société des Ingénieurs civils, of Paris, on the manufacture, at Terre-Noire, of cast steel containing phosphorus. In this communication the general law was put forward that phosphorus might be introduced into steel, on the condition that the proportion of carbon contained in it was diminished; and that the less carbon the steel contained, the more phosphorus might be admitted into it without depriving it of its valuable properties.

The maximum proportion of phosphorus that may be introduced into steel, for rails, is from 0.28 to 0.32 per cent., on the condition that the amount of carbon contained at the same time in the metal does not exceed 0.18 to 0.22 per cent. Any excess of phosphorus beyond this limit renders the metal brittle, liable to be red-short and difficult to roll.

The Author then discusses the relative advantage of the Bessemer and the Siemens-Martin processes, for the production of steel from materials containing a sensible proportion of phosphorus; and, after having given a general preference to the latter, remarks that in making steel by it from scrap iron of any kind, more particularly from old rails, it is important, in the first place, to classify the scrap to be used, according to the amount of phosphorus in it; as the proportion contained in iron rails varies from 0.15 to 0.80 per cent., and only so much of each quality may be used that the percentage in the steel produced shall not exceed 0.30 per cent.

The bed of the furnace, when used for making steel from old rails, is formed of silicious sand in the usual way. The materials to be melted are heated in an auxiliary furnace, before charging them into the melting furnace, to economize the heat of the latter, to admit of maintaining a more regular temperature in it, and to increase the rapidity of working.

The pig iron employed to form a bath may, if sufficiently pure, be of any quality, from the very greyest metal, containing 5 per cent. of carbon and 2 per cent. of silicon, to white iron containing 2.8 per cent. of carbon and no silicon. In the former case, the weight of pig iron required will be less than 10 per cent. of the total charge; in the latter it will be from 30 to 35 per cent. Where white pig iron, sufficiently free from phosphorus, can be obtained at a moderate price, it is advantageous to use this rather than gray iron; taking care, however, to avoid such metal as contains an excessive amount of sulphur. The white pig iron (*fonte blanche chaude*) of Solenzara has been that most used at Terre-Noire.

The following may be taken as the composition of a typical charge:—

	Weight Charged.	Percentage of Phosphorus.	Total Weight of Phosphorus in the Charge.
	Kilogrammes.		Kilogrammes.
White Solenzara pig iron	1,750	0.100	1.750
Light Steel scrap	800	0.100	0.800
Old iron rails, Creusot	850	0.700	5.950
" " Commentry, Fourchambault	500	0.420	2.100
" " Loire	2,000	0.170	3.400
60 per cent. ferromanganese	140	0.270	0.378
Totals	6,040	—	14.378

The pig iron is first melted and raised to a high temperature, and the other materials, having been previously heated in the auxiliary furnace, are charged into

the bath, in quantities of from 4 to 6 cwt., and at intervals of fifteen to twenty minutes. The steel scrap is added first and then the old rails, beginning with those that contain the most phosphorus; as the total quantity to be put in is never quite fixed, it being necessary to add more or less according to the rate at which the oxidation of the metal goes on, and thus it is best to retain to the last that portion of the charge which will least affect the composition of the bath. As soon as so much scrap has been added that the metal begins to become malleable, test pieces are frequently taken from it and beaten out under a small steam hammer into plates 4 to 4½ inches in diameter and about ⅜ inch thick. The earlier tests, taken while the metal is still hard, forge fairly well under the hammer, but are brittle when cold. As the process goes on, the test pieces become more and more red-short, but softer and more pliable when cold. When the last test is soft enough when cold to bend double without breaking, and shows a fibrous fracture, the ferromanganese, previously heated, is added at once, and the metal is tapped as rapidly as possible.

The time occupied in working a charge including the repair of the furnace, is from seven to eight hours, and the average output, per furnace, is 17½ to 18 tons in twenty-four hours. The loss is 6 to 8 per cent., and as there is no elimination of phosphorus in the process, the total quantity contained in the materials treated is concentrated in the steel; so that this will contain, in the case of the charge under consideration, 0.253 per cent., the mean percentage in the metal charged being 0.237 per cent. The 140 kilogrammes of ferromanganese added contain 84 kilogrammes of metallic manganese, equal to 1.4 per cent. of the weight of the charge. This is an average proportion, but when the metal is much oxidized, as much as 2 per cent. more of manganese may be required; and good charges have on the other hand been made, under favorable conditions, with the addition of only 1 per cent. of manganese.

The manganese added is equal to 1.49 per cent. of the 5,650 kilogrammes of steel produced. Of this from 0.650 to 0.950 per cent. is found by analysis to be contained in the metal, the rest passing into the slag.

The metal, before the addition of ferromanganese, contains from 0.11 to 0.12 per cent. of carbon; and as the ferromanganese itself contains 5.50 to 5.75 per cent., the total quantity of carbon in the steel, if none were burned out, should be from 0.245 to 0.265 per cent. The amount found in it is from 0.220 to 0.260 per cent.

The mechanical properties of steels containing phosphorus, made as above described, depend to a great extent, not only on the amounts of carbon and phosphorus that they contain, but also on the proportion of manganese introduced into them.

The following table shows the average deflections, under successive increments of load, of steel rails containing different percentages of carbon, phosphorus, and manganese. The rails were of flange section, 60 lbs. per yard, and rested on supports 1 meter apart. The deflections are given in millimeters.

Load (in Tons of 1,000 Kils).	C=0.45–0.55 P=traces. Mn=0.15–0.25		C=0.15–0.20 P=0.27–0.32 Mn=0.35–0.35		C=0.17–0.22 P=0.28–0.31 Mn=0.50–0.70		C=0.17–0.22 P=0.25–0.77 Mn=1.00–1.20	
	Deflection.		Deflection.		Deflection.		Deflection.	
	Under Load.	Permanent.	Under Load.	Permanent.	Under Load.	Permanent.	Under Load.	Permanent.
12.5 tons.....	2.5	0.0	2.3	0.0	1.9	0.0	1.8	0.0
17.5 "	3.2	0.0	3.0	0.0	2.3	0.0	2.3	0.0
20 "	3.5	0.0	3.4	0.0	2.8	0.0	2.7	0.0
25 "	4.4	0.2	4.4	0.1	3.6	0.1	3.5	0.2
30 "	8.3	3.2	23.8	18.7	12.6	8.3	9.4	5.1
35 "	16.3	10.0	38.7	31.5	33.8	28.5	23.9	18.8
Load causing fracture	45 to 49 tons.		43 to 48 tons.		43 to 48 tons.		43 to 48 tons.	

The behaviour of the four varieties is thus almost identical up to the limit of elasticity; beyond that point, the deflection of the phosphoretted metal is much greater than that of the rail made of Bessemer steel of ordinary quality; but by augmenting the proportion of manganese, the strength and stiffness of the former are increased. The results of tests of the same rails by a falling weight correspond to those of the dead-weight tests; the rails that contain more manganese being stiffer and stronger than those containing less; the rails of phosphoretted metal that contain 1 per cent. of manganese, or more bearing even a heavier blow, without fracture, than rails of ordinary good Bessemer steel, nearly free from phosphorus.

Other tests show that the strength and ductility of phosphoretted steel are increased, much more than is the case with ordinary steel, by casting the ingots large, and putting as much mechanical work on the metal as possible; and that when the phosphoretted steel has been submitted to sufficient working, it has, for metal giving an equal percentage of elongation, a greater tensile strength than steel free from phosphorus. It is probable, also, that the employment of more powerful machinery, rendering it practicable to cast phosphoretted steel in larger ingots, and to put more work on it, will permit of making good rails from metal containing more than the present limit of 0.3 per cent. of phosphorus.

The effect of an increased percentage of manganese, on steels containing but little phosphorus, is to augment the strength and the ductility of the metal to a remarkable degree, as shown by the following table of the properties of varieties of Bessemer metal containing different proportions of manganese:

	No. 1. C=0.65—0.80. P=0.03—0.05 Mn=0.12—0.15	No. 2. C=0.22—0.35 P=0.03—0.05 Mn=0.12—0.15	No. 3. C=0.35—0.45 P=0.06—0.08 Mn=0.95—1.05
Limit of elasticity (tons per square inch)..	21.59	16.00	23.84
Breaking load.....	38.10	29.60	43.61
Elongation % (on test pieces 4 inches long)*	5.00	21.40	21.28

The steel containing about 1 per cent. of manganese has thus a tensile strength greater than that of the harder ordinary steel, No. 1, coupled with a ductility nearly equal to that of the softer and weaker metal, No. 2.

Another property of manganese, when alloyed with steel, is to augment the extent to which it is capable of being hardened or tempered, when heated to redness and cooled rapidly. This may be seen from the following comparison of the properties, in the untempered and tempered states, of steels containing respectively 0.25 to 0.30, and 0.35 to 0.45 per cent. of carbon, together with different proportions of manganese:

(*See Table on following page.*)

Steel containing phosphorus as well as manganese extends less, before breaking, than steel containing the same amount of manganese together with little or no phosphorus, while it has about the same ultimate tensile strength; and it is also less affected by tempering. Thus steel containing C=0.35 to 0.45, P=0.24 to 0.27, and Mn=1.15 to 1.25 per cent., gives the following results:

	Untempered.	Tempered in Oil, from dull Redness.
Limit of elasticity (tons per square inch).....	22.18	19.90
Breaking load " "	42.96	49.14
Elongation per cent. (on test pieces four inches long).....	17.25	9.75

* The ordinary size of the test pieces in use at Terre-Noire is 3.93 inches (10 centimeters) in length by 0.59 inch (15 millimeters) in diameter.

	C=0.25–0.30 P=0.06–0.10 Mn=0.35–0.45		C=0.25–0.30 P=0.08–0.10 Mn=0.50–0.60.		C=0.35–0.45 P=0.06–0.08 Mn=0.50–0.60		C=0.35–0.45 P=0.06–0.08 Mn=0.95–1.05	
	Untempered.	Tempered in Oil, from dull Redness.	Untempered.	Tempered in Oil, from dull Redness.	Untempered.	Tempered in Oil, from dull Redness.	Untempered.	Tempered in Oil, from dull Redness.
Limit of elasticity(tons pr. sq. inch)....	15.98	21.97	17.71	20.857	19.60	22.85	23.83	19.57
Breaking load (tons per sq. inch).....	30.00	39.05	34.99	41.97	36.69	42.85	43.81	53.33
Elongation % (on test pieces 4 inches long)	26 75	21.00	27.00	9.50	23.00	9.80	21.28	1.25

This is a considerably less degree of hardening than that shown by steel containing the same proportion of carbon and only 0.95 to 1.05 per cent. of manganese, together with little phosphorus.

An excess of manganese, while it increases the strength of steel, may at the same time (if carbon is also present in sensible quantity) render it brittle.

THE BRITISH BOARD OF TRADE AND CONTINUOUS BRAKES.

From "The Engineer."

The Railway Department of the Board of Trade is never weary of urging on the railway companies of Great Britain the necessity for using continuous brakes. It is much to be regretted that certain companies appear to have obstinately determined that they will either adopt nothing of the kind until its use is forced upon them, or to retain in their service systems of so-called continuous brakes which have been proved over and over again to be untrustworthy. A correspondence which has recently taken place between the Board of Trade and the railway companies—just published—bears very instructively on this matter. It will be remembered that a correspondence took place last year between the Railway Companies' Association and the Board on the subject of continuous brakes, to which we have already referred at length. A second circular, issued on the 30th of August, 1877, calls the attention of the companies to that correspondence, and states that the Board has been giving further attention to the subject, and from a careful examination of the reports of its officers on the accidents which have occurred during the last few years, the Board has arrived at the conclusion "that three-fourths of these accidents might be avoided, or the results materially mitigated, if the passenger trains concerned had been fitted with continuous brakes." The circular then goes on to point out how desirable it is that a uniform system of brake should be used, at least by all companies working over each other's lines. Thus "the London and North Western, the Great Northern, and the Midland Companies all run through trains to Scotland, which are forwarded over the Caledonian, North Eastern, North British, Glasgow and South Western, and Highland railways. It is, therefore, obvious that the advantage to be derived from any continuous brake system in use on any of these lines will be diminished and neutralized, if at such stations as Carlisle, Glasgow, York, Edinburgh, Perth, and Inverness, the traffic is so arranged that carriages with one system of brakes are attached to trains containing carriages fitted with a different system. The evil can only be avoided if those companies

which interchange traffic with one another adopt one and the same general system." The Board adds with regret that it fails to find any evidence of an intention on the part of the different companies to take any steps towards this end. The circular is especially hard on the Clark and Webb brake, used on the London and North Western Railway, and which "No other great company has ever tried." After referring to the adoption of the Westinghouse and vacuum brakes by other companies, the circular goes on to say:—"Under these circumstances the Board of Trade, whilst recognizing the efforts which some of the companies are making in testing or adopting improved systems of brakes, cannot regard the state of things shown by these papers as satisfactory, inasmuch as it indicates a diversity of opinion and action, and in some cases an absence of progress, which, if allowed to continue, will be most injurious to the character of the companies and to the interests of the public. There has apparently been no attempt on the part of the various companies to take the first step of agreeing upon what are the requirements which in their opinion are essential to a good continuous brake. In the opinion of the Board of Trade these conditions should be as follows:—(*a*) The brakes to be efficient in stopping trains, instantaneous in their action, and capable of being applied without difficulty by engine-drivers or guards. (*b*) In case of accident to be instantaneously self-acting. (*c*) The brakes to be put on and taken off (with facility) on the engine and every vehicle of a train. (*d*) The brakes to be regularly used in daily working. (*e*) The materials employed to be of a durable character, so as to be easily maintained and kept in order. The inquiries and experiments instituted by the Royal Commission on Railway Accidents, and the recent researches into the causes of railway accidents during the last few years, appear to the Board of Trade to leave no doubt as to the importance of the above conditions, and the experience which has been obtained by the companies appears sufficient to enable them to come to some general and unanimous conclusion. There can, therefore, be no reason for further delay, and the Board of Trade feel it their duty again to urge upon the railway companies the necessity for arriving at an immediate decision and united action in the matter."

The circular concludes with a request that particulars of all experiments made with continuous brakes may be sent to the Board to be laid before Parliament.

To this circular replies have been received from a few companies only; we need not reproduce them in detail. The Brecon and Merthyr Railway Company have used Fay's system for many years with excellent results. The Glasgow and South-Western Company use the Westinghouse brake on their Midland trains; and in September, 1877, they had given orders that the vacuum brake should be tried on their Greenock line. The Highland Company have been using Newall's brake since 1863, and are quite content with it. Mr. Knight, of the London and Brighton Railway, states that after making careful and exhaustive trials of the Westinghouse, Barker's, and Edwards' brakes on their line, he and Mr. Stroudley "have concluded that the Westinghouse brake is one of the most efficient, if not the most efficient, of any of the patent brakes which have yet come under our notice;" and we may add here that the directors have recently given orders for the general adoption of this brake on their lines. The Manchester, Sheffield, and Lincolnshire Company have adopted the Smith's vacuum brake, but they argue at the same time that continuous brakes are likely to become a source of danger, and in illustration of this, they call attention to an accident which occurred on the Cheshire lines system. The question raised here is important, and we shall consider the value of the argument in a moment. The North British Company have decided to adopt the Westinghouse brake, the Rhymney Company use Fay's brake; the South-Eastern Company, after taking much credit to themselves for all that they have done to promote improvements in working railways, state that they have decided to adopt the vacuum brake. To the circular and the correspondence which we have just noticed, is added an appendix containing copies of the reports of the officers of the Board of Trade on all recent accidents which might have been avoided or mitigated by the use of continuous brakes, a copy

of each report having been sent to the company concerned. There are in all ten of these reports, dealing with accidents which took place between August, 1877, and the first week in January, 1878. Of these ten accidents no fewer than six occurred on the London and North-Western Railway, by which twenty-nine persons were injured, one was killed, and much damage was done to rolling stock.

The Manchester, Sheffield, and Lincolnshire Company hold, as we have said, that continuous brakes introduce a new source of danger, and they cite, in proof of this statement, a collision which occurred on the 2d of January, at Stockport. In this case the 8.45 a.m. train from Liverpool to Hull ran into a goods van because the vacuum brake would not act, the cause of failure being that a pin came out and the steam could not be turned on to the ejector, and so no vacuum was made. We quite agree with the Manchester, Sheffield, and Lincolnshire Company, that a brake liable to such a derangement may readily become a source of peril; but nothing can be more absurd than to draw the conclusion that because one system of brake failed in this way, all systems must be treacherous. The remedy lies in using brakes which will go on and stop the train if the apparatus becomes deranged, or will otherwise show that they are out of order. The brake, in a word, should be so made that it will report its own delinquencies, and not leave them to be found out at the last moment. We have heard it argued that much inconvenience will result from the introduction of such a novel principle as this; but in point of fact, it is not new in relation to railways. On the contrary, it is followed out on almost every railway in the kingdom. When, for example, the wire for working a distance signal breaks, the arm flies to danger. The result is, that a train *may* be stopped at the wrong time. A train fitted with a continuous brake should be unable to run a mile with the brake out of order, and that this result can be secured is perfectly well known to all who are acquainted with the working of the Westinghouse automatic brake, and one or two other inventions. If the Manchester, Sheffield, and Lincolnshire directors had but used their opportunities they could have cited instances which tend much more forcibly than the Stockport collision to prove that it is quite possible a bad brake may cause accidents. We allude to events on the London and North-Western Railway system, which tend strongly to show that the Clark and Webb brake is entirely untrustworthy. In fact, it appears to be by far the worst continuous brake ever used to any extent on a great railway.

We have already pointed out that no fewer than six accidents have recently occurred on the London and North-Western system, all which might probably have been avoided by the use of an efficient continuous brake. The first of these was a derailment which took place between Moore and Warrington on the 15th of August. In this case the train ran more than half a mile, notwithstanding every effort of the driver to stop it, because the Clark and Webb brake would not act. The second was a collision which occurred on the 3rd of October at Eccles Junction. A fast train from Liverpool to Manchester ran into an engine and van, killing the driver and doing much injury. The train was fitted with the Clark and Webb brake, which could not be applied throughout by the driver. The third accident took place on the 29th of October at Ordsal Lane. The 7 P.M. passenger train, though fitted with the Clark and Webb brake, ran into a light engine. The train was only going at twenty miles an hour, and yet it ran 200 yards in spite of every effort made to stop it. The fourth accident was a collision which took place near Willesden, between a passenger train and a goods train. It was a serious accident, eight passengers and five of the company's servants being injured. The passenger train was only moving at fifteen miles an hour, when the engine took a a wrong pair of points and ran into a train standing seventy-two yards from the points in a siding. In this case it seems that the brake did not act with sufficient promptitude. Had it been really efficient the train would not have run much more than one-third of the distance. The fifth accident took place at Duston, between Northampton and Blisworth, on the 7th of November; here again a passenger train ran into a goods

train. No continuous brake was in use. A sixth accident, which occurrred on the 9th of December, near Blaby, is very instructive. The engine of a mixed goods and passenger train broke away and the train followed and ran into it. In this case no accident would have occurred had the train been fitted with an automatic brake, which would have at once gone on the moment the engine broke away.

It will be seen from these examples that a so-called continuous brake may prove a source of much danger. Sensible people will say, why use such a brake?

The Board of Trade has spared no pains to induce the London and North-Western Company to abandon an arrangement which seems invariably to fail when it is most wanted. In reply to an urgent letter on the subject, dated 1st of October, the Board of Trade received on the 19th of the same month a letter saying that "the directors were still sanguine that when all the appliances are completed as they intend them to be, the system they have adopted will comply with the required conditions." The Board of Trade, however, has told the company very plainly that it is "unable to entertain much hope that the expectations of the directors will be realized," and it has since specially called the attention of the company to every accident bearing on the value of the Clark & Webb brake; but so far as the parliamentary paper before us goes, it seems that the company have taken no notice of these communications. Yet it may be taken for granted, we think, that a system which cannot be made to work by so competent an engineer as Mr. Webb, with all the resources of Crewe to aid him, can hardly be made to work at all, and should be abandoned forthwith.

ON THE CHEMISTRY OF STEEL.

By WILLIAM BAKER, A. R. S M., F. C. S., F. Inst. Chem.

From "Iron."

The facts which are known about steel have hitherto been distributed on the one hand amongst manufacturers, practical steel melters, and other workmen. But the facts have been of a certain kind for each of these observers, and comparatively few persons have had the opportunity or the inclination to grasp them all, and correlate them for future guidance, even for practical purposes. On the other hand, a different class of facts have been known by chemists, such as relate to the general properties of matter and the special properties of iron and its compound, as far as they can be studied in the laboratory, or by the occasional sight of some of the large metallurgical operations of the factories.

The time, I hope, is passed when these observers of different classes of facts were supposed to stand in some sort of opposition as men of theory and of practice; but my observations of the numerous unexplained difficulties occasionally occurring in the best conducted manufactories, convince me that a much greater certainty in results would have been attained if these scattered observations had been tested by comparison, and reviewed in a comprehensive manner by a trained scientific mind.

It is not for me to say how far one is justified in asking manufacturers to reveal the secrets which they suppose have led them to success; and I imagine, if any of you can buy a common iron, and make as good steel as your neighbor, who buys a higher-priced article, you would prefer to keep the knowledge to yourselves. The economy of material and of money which would result from the better knowledge obtained by an opposite policy, would, however, bring about the greatest benefit to the greatest number, and leave plenty of scope for fair rivalry in commerce.

I must premise that I am not acquainted with all the curious observations which may have been made in a steel factory, and with which many of

you are quite familiar; but my intention is to exhibit to you a chemist's view of the nature of steel, and to point out the path for experiment and the probable extent of its track.

Characters of Pure Iron.—In order to understand steel, we must begin by an examination of the properties of pure iron, or at least of iron in the purest form attainable.

The method originally recommended by Berzelius to obtain pure iron from the wrought iron of commerce was to fuse the filings with one-fifth of their weight of pure peroxide of iron under a flux of glass free from metallic impurities. Percy did not find the product thus obtained free from carbon. The specific gravity was 7.87 after hammering. The fracture was largely crystalline, greyish-white, and the metal was soft and malleable. Electro-deposited iron has been produced which did not harden when plunged red-hot into mercury, and which dissolved in dilute acid without the peculiar odor given off by every kind of commercial iron. These results prove the absence of carbon, but do not exclude the presence of nitrogen, which I am disposed to think, from the physical characters of the metal, may have been combined with the iron. The specific gravity was 8.1393, and the metal was susceptible of a high polish.

The investigation of the production of pure iron, and an examination of its properties, are well worthy the attention of chemists who have sufficient leisure; and I hope, if the British Association meet in Sheffield, the members may be inclined to take up again the question, which has somehow dropped out of the proceedings after it had been entrusted to a committee for report.

Two observers, Meidinger and Kramer, agree in stating that about 1.5 per cent. of nitrogen was found in precipitated iron.

I possess some iron containing nitrogen, which I obtained by passing dry ammonia over it at a red heat. It is a brittle steel-grey alloy, and contains 5.76 per cent. of nitrogen, represented nearly by the formula, Fe_4N.

Iron crystallizes in the cubical system. Its structure may be studied in masses which have been submitted for a long time to a heat short of fusion. The fracture is largely granular, and possesses a brilliant metallic luster. A section of such iron, when highly polished and etched for a microscopic object, is very characteristic. It exhibits a network of irregular hexagonal forms, which may be at once recognized in all samples of wrought iron, whatever their source. The Bessemer iron, before the addition of spiegeleisen, exhibits the same pattern as a bar of wrought iron or a wrought iron axle, the only difference in the various samples being in the size of the crystals. A slice from a Bessemer ingot still exhibits the same network of hexagonal-shaped crystals, but possesses, besides, some harder portions, due to the spiegeleisen, which strike across the spaces like bright silver threads, and the crystals themselves, seen by the light of a parabolic reflector, have more distinct prismatic colors.

It is easy to understand how a mass of iron deprived of carbon, and having these large crystals developed, is deficient in tenacity. The Bessemer ingot, however, when hammered and rolled, has a very different appearance, and cannot be distinguished from ordinary crucible steel. The nearest approach to pure iron we have on the large scale will be found in the softest bar iron of commerce, and I will examine how this stage of manufacture is reached, and what elements may be expected to be contained as impurities.

Production of Steel from Cast Iron.—Originally steel was produced, as it is to this day in India and less civilized countries, by working the bloom or mass of iron reduced from rich ores in a charcoal-furnace under the blast. Afterwards cast iron was first made, and although Siemens has again introduced a direct process of reduction from the ore, we may consider that, practically, to make steel, we must start with cast iron.

Cast iron presents us with a metal containing carbon as an essential constituent, and the following elements besides as impurities:—Silicon, sulphur, phosphorus and manganese. It may also contain copper and traces of cobalt, nickel and titanium.

The art of the smelter consists in adjusting the charge of the furnace in such a manner that when the iron is reduced it may have time during its descent in

the blast-furnace to absorb the desired quantity of carbon, whilst the other elements, or at least the hurtful elements, such as sulphur and phosphorus, should be taken up by the slag or cinder.

Iron absorbs carbon when heated in contact with it at a bright red heat. It will also take up carbon from pure carbonic-oxide gas, and this, it must be remembered, is the chief gas present in the furnace. Accurate experiments are wanting as to the rate of absorption for varying temperature and pressure; but I have found that whereas at a moderate red heat carbonic oxide is decomposed if passed in excess over red-hot iron, when it is passed through the melted metal containing already about 1 per cent., no increase was observed at this far higher temperature. At the high temperature of the blast-furnace, silicon is also reduced, and absorbed by the iron. A siliconized pig-iron is now a variety which is of great service in the Bessemer works for producing a "hot-blow;" and I have analyzed some grey pig-iron containing as much as six and seven per cent. Sulphur is an impurity which is not so much dreaded as formerly; as it is easy, by a proper addition of lime and by management of the furnace, to prevent more than a trace appearing in the pig-metal.

This cannot be said of phosphorus, which is present in iron ores as phosphoric acid. The process of smelting, as carried on in the blast-furnace, unfortunately effects the reduction of the acid, and practically the whole of this element is found in the iron produced. Manganese appears more or less in pig-iron, according to the amount of its oxide in the ore employed. When a notable quantity is required in cast iron, as for spiegeleisen, the charge must be adjusted so as to allow for some of it being also found in the slag. As a rule, when iron and manganese oxides are together, the whole of the iron oxide is reduced before the manganese; so that when a good fusible cinder is produced of the usual composition—silicate of lime and allumina—it is common to find a proportion of manganese oxide replacing the lime.

The traces of other metals occurring in cast iron rarely affects steel, as they disappear in the processes of manufacture.

Combination of Carbon and Iron.—The combination of carbon with iron is so extraordinary, and presents such unexplained facts, that I must dwell for a short time on this part of my subject. Starting with pure iron, it is found that the addition of a very small proportion, say 0.2 per cent., imparts the property of hardening slightly when heated and suddenly cooled. With increasing quantities of carbon this phenomenon becomes more striking. With about 1.5 per cent., steel, after hardening, acquires its maximum hardness with maximum tenacity. Beyond this quantity greater hardness is obtained, but there is a loss of tenacity and property of being welded. The maximum amount of carbon which will combine with iron alone, has not been yet ascertained. When manganese is present, as in spiegeleisen, it may rise to a little above 5 per cent., but more frequently is slightly below this figure.

We have, however, this remarkable fact to account for. Carbon exists combined chemically, and also in a free state, as in the form of graphite, and this distinguishes white from grey iron. Chemical analysis affords proof of this fact, and solution of the iron in acid actually discloses scales of graphitoidal carbon.

White iron, on the contrary, dissolves with scarcely a trace of carbon being left behind. "Gray iron has a higher melting point than white iron, and on fusing passes almost instantly from the solid to the liquid state when it is very fluid; whereas, white iron at lower temperatures becomes first soft and then pasty before melting" (Percy).

These facts, to my mind, point to the presence of a definite carbide in white iron, which may be considered in solution with the iron, and the pasty condition is due to the fact that the iron solidifies before the carbide. The crystallization of white iron is quite distinct from iron alone. We have, then, to account for the higher melting point and quick solidification of grey pig iron, and I think, if we consider the fact of the specific heat of carbon being double that of iron, we have a key to the explanation. The melting point of iron *per se* is known to be very much higher than iron containing carbon in combination, but when free carbon is dissolved

in the iron, the heat retained by it, by reason of its specific heat, may favor the fusion. What conditions determine the form in which carbon is found in iron, have not been altogether satisfactorily made out. We know that when bar iron is heated in contact with charcoal, as in the steel-converting furnaces, the carbon enters, and is found in the combined state. I examined some bars once which had run from overheating in one of these furnaces, and wherever fusion had taken place the bar was no longer blister steel, but grey iron. The percentage of carbon was only a trifle higher in the grey portion.

In some experiments I lately made, I passed chlorine, carbonic acid, and carbonic oxide frequently though molten iron of the quality No. 3 Middlesborough pig-iron. I found it very difficult to obtain the ingot in the form of grey iron by the artifice of very slow cooling. It is probable the presence of phosphorus to the extent of one-half per cent. had considerable influence in keeping the carbon chemically combined.

Silicon is also supposed to occur in the graphitoidal state in such varieties of iron as No. 1 Bessemer pig, but in steel it is, without doubt, in chemical combination entirely. Sulphur and phosphorus both render iron harder and more fusible.

Conversion of Cast Iron into Steel.—Having reviewed thus shortly the most important facts connected with the presence of these substances in cast iron, let us examine how far the processes of conversion of pig-iron into steel effects their elimination.

The pig-iron is puddled to make bar iron. This process is essentially an oxidizing one. Silicon oxidizes first, then, as the carbon is removed, sulphur and phosphorus are also oxidized and pass into the slag. Only towards the end of the process, when the heat is much increased, the phosphorus is retained by the powerful affinity iron has for this element at high temperatures.

Mr. Lowthian Bell has lately brought out this fact very prominently by a series of carefully executed experiments, together with analyses, although it cannot be said that the behavior of phosphorus under the conditions were unknown. I mean, it was known that with an oxidizing cinder, phosphorus could be removed, and that at the end of the process, if the slag were still in contact, this element would again return to the iron. However, Mr. Bell has more accurately defined the conditions of its elimination in his paper read at the last meeting of the Iron and Steel Institute.

If we turn to the Bessemer process, we find that, with somewhat different conditions, we have also to deal with an essentially oxidizing reaction. The slag, however, which is formed is not basic; the oxidation is direct by means of the oxygen of the air, and no phosphorus is eliminated. All the other substances may be removed most completely, silicon first, carbon and manganese afterwards. We approach the production of fused wrought iron, and one reason we are not able to succeed in getting the metal into the ingot moulds appears to be the enormous volume of carbonic-oxide gas which it has absorbed. Another is the sudden oxidation of the iron itself, which, following the order of affinities for oxygen at this high temperature, begins to burn when the last portions of carbon are removed.

The addition of metallic manganese has a wonderful effect in reducing the oxide and liberating the occluded gas, so that, without going to the extent of oxidation which I have indicated, spiegeleisen, or ferro-manganese, enables us to obtain an ingot which may contain only 0.25 per cent. of carbon; silicon, perhaps, to the amount of 0.1 per cent., sulphur in traces, and, lastly, according to the quality of the original pig-iron, phosphorus from 0.01 to 0.05 per cent.

Going back, however, to the puddled bar iron, which has been washed in a bath of slag, balled up and hammered into bar, we have a tough metal, which is, however, not homogeneous, because it has not been fluid during the last stages of the operation. It contains portions of slag and oxide of iron besides the impurities in combination. It is true the latter may be in very insignificant quantities. Silicon is often recorded to the amount of 0.3 per cent.; but, in many cases, this includes the silica due to intermixed slag.

It is the oxide of carbon mechanically enclosed in the bar which produces the blisters on the converted bar. The regularity of the blisters show the work

which has been put upon the metal in balling up and treatment under the hammer.

I will now follow the bar to the converting furnace, where it is heated with charcoal at a full red heat. The atmosphere of the cementing pot is undoubtedly chiefly carbonic oxide. Hydro-carbons retained in the charcoal, and possibly cyanogen, with atmospheric nitrogen, may also be present. Whatever may be the value of the last-named gas for conversion of iron into steel, I can affirm confidently that pure carbonic-oxide gas alone, without actual contact with charcoal, is all-sufficient for the purpose.

Of the impurities, silicon, manganese and phosphorus remain, whilst sulphur is slightly diminished in its proportion. The charge itself, gaining in weight by the operation, will of course exhibit a slight diminution in percentage composition of silicon, phosphorus and manganese.

The iron has now acquired the desired proportion of carbon; let us examine what changes can take place in melting the same. Silicon may be slightly diminished by oxidation. Sulphur, if existing in any appreciable proportion, is also diminished if manganese be added, as is usually the case. Phosphorus remains untouched. Silicon may sometimes be increased in mild steel, which requires a high temperature for fusion in consequence of the reducing action of carbon in the pot upon the silica in the clay.

But bar iron may be melted with charcoal direct, or with spiegeleisen, in order to produce cast steel, and certain differences of character are alleged to be discovered in the products of these three operations when the same bar iron has been employed.

Now, with all respect to the observers, who, I am sure, have founded their opinions upon practical results, I venture to suggest that the observations and experiments to determine these differences have not been put into the scientific form which will alone educe the truth. A scientific method would first establish identity of chemical constitution, and next, the mechanical tests should be rigidly the same, and of such a character as to be independent of opinion and capable of being recorded in figures.

When charcoal is used, I cannot see, as a chemist, that any appreciable amount of foreign matter, except the carbon, is in contact with the iron, and precisely the same quantity of steel ought to be produced as when blister steel is melted.

Spiegeleisen does, however, introduce manganese, traces of sulphur and phosphorus, and not unfrequently copper, which may all alter the constitution of the steel.

Again, the comparisons should be made with the same temper, and the ingots tested by a machine using exactly similar dimensions of each kind of steel, as in the well-known experiments of Kirkaldy. There is an excellent report on the mechanical properties of steel in the British Association Report of 1867, by Fairbairn, which would be doubled in value if a chemical analysis of each specimen had been recorded. Even now it is quite possible that some typical samples might be recovered for this purpose.

Steel Melting.—Any one who has cast leaden bullets knows that when the lead is hot and the mould has got hot too, the bullet is piped. It is so with steel. Well-melted steel pipes, and any substance which confers fusibility to steel, like ferromanganese, tends to make it pipe.

The carbonic oxide which is absorbed by melted steel produces an opposite effect; the steel rises in the mould, and is full of "honeycombs" or gas bubbles. The proportion of this occluded gas and its relation to different qualities of steel, or different behavior in "teeming," have not yet been properly worked at, and in my opinion are well worthy of investigation.

In what manner the physical characters of steel are influenced by the time and the temperature of melting, and by the interval between the pulling out and the teeming into the moulds, are subjects which require definition and some accurate measurement before we can reconcile some of the statements made by men of undoubted experience.

Perhaps the instrument of research which is most needed is a good pyrometer, and I think it is not improbable that some spectrum observations may lead to the discovery of a useful guide to

the measurement of high temperatures. The compression of steel whilst in the pasty state before complete solidification has, in Sir Joseph Whitworth's hands, produced ingots remarkably free from the honeycombed structure caused by bubbles of gas. The difficulties in practice seem to me to be in dead-melting the steel in the first place, and then, after removal from the furnace, choosing the period when it will pour without piping.

The grand point aimed at by all steel melters is to obtain tough steel, and they mean by this, I presume, a steel hard enough for the purpose required, with a maximum tenacity. At least, more than that is not possible; for toughness and hardness are really opposite qualities, and the utmost that can be attained is a suitable relation between these properties for a given purpose.

It is certain that the purest steel is the toughest. Absence of silicon, sulphur and phosphorus are, at all events, essential for the best results. It is yet to be proved whether a small proportion of metallic manganese imparts more tenacity to steel; but there is some ground to believe that it does. I think I am right in stating that it confers the property of standing repeated heating, which is known as "body" in steel.

Besides carbon, we know that the three elements, silicon, sulphur and phosphorus, singly or all together, will harden steel. The experiments made by the Terre Noire Company show that when the carbon is replaced by phosphorus, and the former is not more than 0.2 per cent., a serviceable rail can be made, containing as much as 0.3 per cent. of phosphorus.

It is also established that a good wrought iron may contain as much as 0.2 per cent. of phosphorus, whereas the attempts to make tool steel of such a material would be a failure. In fact, phosphorus cannot be admitted when carbon is present in the proportion which confers the properties of hardening and tempering.

Time will not permit me to enter fully into the effects of other materials which are likely to be used methodically in the production of certain kinds of cast steel, such as wolfram or tungsten, chromium and titanium. Generally it may be said that they produce greater hardness and closeness of grain, but none appears to play the part of carbon in conferring the property of hardening and tempering.

This interesting phenomenon belonging to ordinary steel has not been thoroughly investigated, and the influence of the occluded gases I think may furnish a new field of observation.

I have thus reviewed the present state of our knowledge of the chemistry of steel without quoting authorities whose opinions I have myself carefully studied and compared with my own observations. The subject demands a leisure which I have long looked for in vain, whilst engaged in the daily work of my laboratory. What I have done in practical experiments convinces me that a much greater certainty would accompany the operation of making steel if some of the questions I have indicated were decided by a well-conducted and scientific research.

STEEL MARINE BOILERS.

From "The Engineer."

It will be seen from a report which we publish on another page, that Mr. W. Parker, chief engineer surveyor, and Mr. James Milton, engineer surveyor, to Lloyd's, advise that society to permit in future the use of steel boilers, the shells and stays of which may be made 25 per cent., and the flat plates 12 per cent., smaller in scantling than would be admissible if similar boilers were made of iron. Lloyd's have already sanctioned the use of steel in shipbuilding, and the adoption of the report of Messrs. Parker and Milton will constitute another step in advance. It will be seen, however, that steel is only to be used under cer-

tain stringent regulations as regards the tests to which the plates are to be subjected; and it is not too much to say that it is only within a very recent period that it became possible to obtain steel with anything like certainty, and at a reasonable price, which would meet the demands thus made on it. A very elaborate inquiry has been conducted by Mr. Parker, and the result is that steel capable of standing a tensile strain of 28 tons to the inch, and elongating 20 per cent. before fracture, can now be obtained; and it is this really wonderful metal that steel boilers are to be made of. It is evident that nothing would have been gained by sanctioning the use of steel of a quality which could not be had; and we feel certain that gentlemen so careful and competent as Mr. Parker and Mr. Milton would not have introduced the stipulations laid down in their report had they not been convinced by practical experience that a metal existed which would comply with them. This metal is now made by at least three great firms, and it is worth notice that it can be obtained at a reasonable price—the quotations for boiler plates 1in. thick ranging from £15 to £21 per ton, with different makers. But even this excellent metal requires very careful handling, and on this point a few words may not be out of place here. Those who attempt to make a steel boiler as they have made iron boilers, will soon find out to their cost that steel is a very different metal indeed from iron.

In the first place, holes in steel boiler seams should always be drilled. When steel plates are punched they lose from 26 to 33 per cent. of their strength. A paper was read by Mr. Sharp before the Institution of Naval Architects in 1868, in which the author gave as the result of his experience a loss of 33 per cent. Mr. Kirk, in a paper read before the same body in 1877, gave similar figures; so that it will be seen that the improvements effected in the mode of manufacturing steel during nine years have left this point quite untouched. Mr. Webb, of Crewe, states that the loss of strength is but 26 per cent.; but Mr. Webb in punching steel uses a die-block with a hole much larger than the punch, and the holes produced are conical with the large side down. The investigations of Mr. Parker fully confirm the teachings of past experience, and a material which is apparently almost as ductile and "kind" as lead, no doubt loses about one-third of its strength when punched. This is a curious fact well worth proper investigation. All sorts of other defects in steel appear to be curable, but this has hitherto remained unaffected by any change in the process of manufacture. It has been shown, however, that the plate may be restored after punching to nearly if not quite its full strength by annealing. The word is not happily used in this case, the plates not being annealed at all in the true sense of the term, but simply reheated. It is a mistake to assume that if they are not cooled down slowly after heating they must become brittle. The plate might be thrown into cold water when red-hot without injury, provided it could all be cooled down at once. A prolonged process of cooling is required only because if the work is hastened some portions of the plate may be cooled more quickly than others, and the value of the so-called annealing process will be lost. It was hardly known until now that steel plates suffer most as much from shearing as from punching, and that similar precautions must be taken to restore the strength of the material. It appears, however, that notwithstanding these drawbacks, if the advice given in the report be followed, especially as regards flanging plates, steel may be worked into boilers with the certainty that a good result will be obtained.

As regards the proportions to be given to the riveted joints of steel boilers, Messrs. Parker and Milton do not speak positively. We may say that experiments are still in progress to decide this point, and that for the present it is considered best that for each boiler to be constructed a direct experiment shall be carried out to ascertain the proper proportions. Enough is known, however, to show that the proportions used with iron will not do with steel. The metal is so soft that it cripples or puckers up behind the rivets, which can't in the plates. The holes become oval and the seams leak long before anything nearly approaching the bursting pressure is obtained. Excellent results have been got with a double chain riveted joint, the plates being $\frac{11}{16}$in. thick, and the rivets $1\frac{1}{16}$in. thick, pitched

4 in. apart. This joint had a strength of 74 per cent. that of the plate. But we do not put these forward as the proportions which ought to be always adopted. No trials have been made, we believe, with oval rivets, the value of which might be worth testing.

No doubt many of our readers will ask what can be gained by substituting a material so peculiar, and requiring such careful manipulation, for iron. The reply is, that on the whole a steel boiler will cost less money than an iron boiler of the same power. It is very rarely that anything better than B B iron is used for the shells of marine boilers. This is good for from 18 to 21 tons per square inch, 19 tons may be taken as almost the average. If we substitute for it a metal which will bear 26 tons, a corresponding reduction can be made in weight, or an increase can be made in pressure. It must not be forgotten that the consideration with which steel must be treated when being worked into a boiler is, after all, not costly. The reheating plant is very simple; and the operation of flanging can be readily effected *en masse*, instead of a few inches at a time, if proper cast iron blocks are provided. The marine boiler makers of Great Britain might learn something concerning the flanging of steel from Messrs. Garrett, of Leiston, who have long used Piedbœuf's machinery for this purpose, with great success. Once a steel boiler is made, the risk of injury to the plates appears to be over, and, so far as can be learned, something is obtained, which is stronger, lighter, and more durable than any iron boiler. The only thing to be feared is pitting and corrosion, and on this point it is impossible to say much with certainty, as the number of steel boilers which have been at work for any time at sea is extremely limited. We have reason to believe that the moment Lloyd's sanction the use of steel boilers, a considerable number will be made. Many shipowners want to carry pressures of 120 lbs. in boilers 12 feet and 13 feet in diameter, and it is found that iron plates 1¼ inch thick cannot be made tight, or kept tight at the joints; that they are very expensive to work up, and that the quality of such plates is by no means all that could be desired. As pressures as great as 90 lbs. are already carried at sea, if steel be substituted for iron, instead of reducing the scantlings 25 per cent., the pressure may be increased 33 per cent., and 90 lbs. steam might thus become 120 lbs., or even a little more, for it is by no means impossible that the factor of safety in the steel boiler may yet be reduced below the six to one limit now insisted upon by Lloyd's rules.

REPORTS OF ENGINEERING SOCIETIES.

Engineers' Club of Philadelphia.—At a meeting of the Club, held February 16th, twenty members were present, and ten new members were elected. Mr. Chas. A. Ashburnet read a paper entitled "Where is Petroleum found?" After noticing some of the many points of interest concerning our petroleum industry, which have been brought before the public during the recent "pipe line" discussions, the author gave a general sketch of the various "Oil bearing sands," giving the geological position and character, and the quantity and quality of petroleum which they at present produce. The oil regions of Pennsylvania were divided into three districts, viz.: the Southwestern, South of the Ohio River and West of the Monongahela River; the Western, along the Allegheny River and tributaries between Pittsburgh on the South, and P. & E. R. R. on the North; and the Northern District, North of the P. & E. R. R. extending into New York State.

In Pennsylvania, three thousand feet of the rocks of the Carboniferous and Devonian ages have been found to contain mineral oil. The highest producing sand occurs in Washington Co., 165 feet below the Pittsburgh coal seam, the lowest in McKean Co., 3,200 feet below the geological position of the same coal bed. The Bradford oil, in McKean Co., comes from a horizon 400 feet above the lowest.

On a basis of a daily production of 40,000 barrels, each of the nine different sands in which oil is found was given its respective production.

In speaking of the percentage of risk which the producer experiences in obtaining dry holes, the South-Western district was stated to be the most treacherous, and the Northern the safest, for in the latter the proportion of dry holes is only three wells in every hundred.

Specimens of the "sands" and crude oils were exhibited and formed an interesting feature of the paper.

Mr. Geo. H. Christian, Jr., followed with a paper on the "Lowe Gas Process," which was illustrated by a large sectional drawing, and a view of the new gas works at Lancaster, Pa. Mr. Christian gave a full and interesting description of the plant in one of the works of the American Water Gas Co.

The various chemical changes which take place in the course of manufacture were noted and the cost of manufacture, wear and tear of plant, &c., were given. The advantages possessed by gas made under this process were

clearly shown, and the reasons why this superior and economical gas has not been introduced into our city were stated to be entirely of a political nature.

At a meeting of the Club, held March 2d, twenty two members were present. Mr. Rudolph Hering read an interesting paper on "The Sewerage of Philadelphia." This is a subject which is all important to the welfare and health of the city, and one which has received close and careful study from the author. An abstract of this paper will be given in our next issue.

A paper on the "South Street Bridge," by Prof. L. M. Haupt was read. Estimates of the pressure on the piles, forming the foundations for the piers in the Western approach, had been calculated from data obtained from drawings in the office of the City Engineer. Prof. Haupt thought that as the piles were driven through or into soft mud, which is inundated at every tide, the pressure placed upon them was in excess of their bearing power in such soil, and the cause of the fall of the structure.

This paper brought out very general discussion.

Mr. Geo. Burnham, Jr. gave a general description of the masonry work of the bridge and presented a plan which might have been used to save part of the structure. At the second pier east of the Pennsylvania R. R. the piles were driven through 15 feet of mud to a bed of gravel. Only the north end of this pier sank, the south end remaining firm. Mr. Stauffer stated that at the railroad abutment the gravel bed was within a foot of the surface; it seemed to have a regularly sloping surface toward the river, where the piles were driven through 45 feet of mud before reaching it. Piles were all driven with a 2,000 lb. hammer, and received, as a final test, four blows from the hammer with 36 feet fall, when one inch downward motion was the maximum allowable for each blow.

The cause of the failing of the pier is not known and cannot be definitely stated until the rough examinations have been made. The fact that within twenty-four hours of the final crash there was not a vertical crack in the masonry, though the pier was sinking to the north, proves that the grillage must have been perfect.

The estimated load on the piles under the pier was 2,000 tons, amounting to 23 tons on each pile. According to Rankine, the piles were good for 8 tons frictional value, leaving 15 tons on the toe of the pile. The tremor produced in the piles by travel on the bridge would loosen them sufficiently to allow the percolation of water down their sides and finally throw the whole weight on the toes of the piles. If the bed of gravel was merely a thin bed or pocket the water probably softened it allowing a bunch of piles at the north end of the pier to drop through to the mud.

Mr. Hering did not think the removal of the roadway above the sinking pier was a disadvantage; Mr. Stauffer held that every block of coping, paving, etc., which was jammed in the invert arch in the roadway caused by the sinking of the pier, helped to convey weight to the sound piers on either side, and that their removal threw the additional weight on the failing pier. An expenditure of $500 in placing the rods across the arches through the skew backs would have saved seven out of the nine arches. If time had allowed to put in centres, as was proposed, they would not have been of much value without these tie rods.

The discussion of the South Street Bridge was made the special order for the next meeting.

CIVIL AND MECHANICAL ENGINEERS' SOCIETY. —At a late meeting of the society a paper "On Chimney Shafts" was read by Mr. R. M. Bancroft, past president of the society. After drawing attention to the wide difference of opinion between various authorities who have written on the subject, especially with regard to parallel and taper flues, and whether chimneys should have a regular batter or outline similar to the theoretical diminution of columns, which it is said should have a slight swell in the center of its length, the author proceeded to describe upwards of forty chimneys of which the different owners and designers had supplied him with particulars. These he had tabulated, to show, at a glance, height, thickness of wall, proportions of diameter to height, weight, cost, time of building, &c.; and drew attention to the designs of caps, and in one case noted where a cap had cost £700 in repairs and removal after the stack had been completed. Mr. Bancroft then drew attention to the difficulties in straightening chimneys when out of the perpendicular, and mentioned several successful cases where this had been done.

AT a late meeting of the Edinburgh and Leith Engineers' Society, a paper was read by Mr. Alexander Leslie, Member Inst. C.E., on "The Liability of Reservoir Embankments to Failure." After stating that great care should be taken to have the base of the embankment on perfectly solid ground, the writer went on to describe the construction of the puddle wall and trench, pointing out the sources of failure which are apt to occur, and giving examples from his own observations of a very great number of embankments. He mentioned that no wood used in the construction of the puddle trench must be left in, as the water is sure to creep along the smooth surface between it and the puddle, and so, in time, cause serious injury. He also stated that the practice of using wagons and rails for tipping the materials of the embankment cannot be too strongly condemned, as loose stones are sure to find their way to the bottom, and make there a more or less porous layer. After describing the method of pitching the surface, and also of constructing the waste weir and channel, Mr. Leslie gave instances of very destructive failures, such as the Dale Dyke and Holm Firth reservoirs, and discussed the causes of them. On speaking of the drawing-off pipes, it was stated that every caution should be taken to prevent any water from creeping along the surface of the pipe, as, sooner or later, serious leakage would result.

LIVERPOOL ENGINEERING SOCIETY.—At the meeting of this society, held on Wednesday evening, January 30, Mr. Arthur J. Maginnis read an instructive and interesting paper on "Atlantic Lines and Steamships." The author, in the early part of the paper, gave a short review of all the important companies and vessels which have been engaged in the Atlantic trade since 1840, in which year the first Cunard steamship sailed. After detailing the various schemes, more or less successful, which have from time to time been tried for reducing the passage between Europe and America, Mr. Maginnis drew attention to some of the more important improvements, considered from an engineering point of view, introduced in the vessels of the White Star and other lines. Among these may be mentioned direct acting compound engines; and in the hull of the vessel itself, the proportions of length and breadth are increased, and the bulkheads carried up 16 feet above the load line. The advantage of these improvements may be estimated from the fact that while the speed of Atlantic steamers has increased from 8.3 knots to 15.6 knots, the consumption of coal, per indicated horse power, has decreased from 4.7 cwt, and the consumption of coal per ton of cargo delivered has decreased from 48.35 cwt. to 44.5 cwt. The paper included some instructive tables carefully compiled from official sources.

IRON AND STEEL NOTES.

STRENGTH OF IRON AT DIFFERENT TEMPERATURES.—G. Pisati and G. Saporito-Ricca find that the strength of iron at different temperatures shows peculiar irregularities. The strength in a wire which is exposed to a dull-red heat diminishes, with increase of temperature, from 14° to 50°, then increases to 90°, diminishes rapidly to 120°, remains constant to 200°, sinks slowly to 235°, then comes a sudden increase, which is followed by a gradual diminution. The strength is greater at 300° than at 140°.—*Dingler's Journal.*

STEEL BOILERS.—The report of Mr. William Parker and Mr. James Milton, Chief-Engineer-Surveyor, and Engineer of Lloyd's, on Steel Boilers, is an important and carefully-prepared document. After careful enumeration of the experiments made, and the evidence collected, the conclusion is arrived at that, "in the construction of steel boilers, greater care and attention must be exercised with the workmanship than is required in the case of iron boilers;" that, although the corrosion of the steel boilers examined is excessive, they may, "if made with the care that this material requires," eventually prove as durable as iron boilers, and, that it will be a question whether a considerable reduction in the factor of safety may not be found compatible with perfect safety and efficiency. It is therefore recommended that a reduction from the scantlings prescribed by the rules for iron boilers be made in the shell plates and stays to the extent of 25 per cent,; and in the flat plates not subject to the action of heat, to the extent of 12 per cent., on condition that the material have an ultimate tensile strength of not less than 26, and not more than 30 tons per square inch of section: that a strip cut from every plate be tested; that the holes be drilled, or if punched, the plates be afterward annealed; that all plates, except those in compression, that are dished or flanged, be afterwards annealed; and that the boilers be tested to not less than twice their working pressure.

RESISTANCE OF STEEL AND COMPOSITE PLATES.—In continuation of the experiments which took place at Portsmouth shortly before Christmas, with the view of ascertaining the power of resistance of steel and composite (steel and iron) plates, two plates, manufactured by Messrs. John Brown & Co., the Atlas Works, Sheffield (Ellis's patent), were on Wednesday subjected to the same test on board the *Nettle*, target ship of Her Majesty's ship *Excellent*, in Porchester Creek, at the upper part of Portsmouth Harbor. On the former occasion the experiments were made with four plates, three supplied by Messrs. Cammell & Co, and the other by Sir Joseph Whitworth. The plates operated upon on Wednesday were respectively 7 feet 9 inches by 6 feet 8 inches, and 7 feet 6 inches by 6 feet 6 inches, and 9 inches in thickness. Three shots were fired at each plate from a 12-ton 9-inch muzzle-loading rifle gun, at a distance of 30 feet, the charges being 50 pounds of battering pebble powder, and the projectile called chilled Palliser shots 250 pounds in weight. The three shots fired at the first plate each penetrated about 10 inches, and created more than a dozen deep fissures, some penetrating through the plate, besides superficial cracks. On the second plate being fired at, the penetration of the first and second shots was about 9 inches; the third shot proved most damaging, the left section of the plate being carried away, and falling with a crash on the floor of the floor of the battery.

FINE STEEL CASTINGS.—A patent has been recently taken out by Mr. A. J. Nellis, of the Pittsburg Agricultural Works, in favour of a process for making irregular-shaped castings, such as plough-shares, out of fine tool steel, of any desired percentage of carbon, without annealing, as in the ordinary "steel casting" processes. In the ordinary method of making steel castings, it is necessary for the steel to be very high in carbon, in order to be fluid enough when melted to run into a fine casting, and the excess of carbon is removed after the casting is made by a process of annealing which requires from ten to twenty days. By Mr. Nellis's method of making castings, low carbon steel, or ordinary tool steel, may be employed if desired. The mould in which the casting is formed is impregnated with combustible materials, which takes fire the instant that the melted steel comes in contact with the mould. An intense heat appears to be generated, which retains the steel in a perfectly fluid condition till it reaches the smallest corners of the mould, and an agitation is caused by which all air and confined gases are allowed to escape from the metal, thereby making the casting free from blowholes. One theory of the action of this

process is that the combustion of the materials with which the sand is impregnated consumes all the oxygen of the air within the mould, and that the remaining gases have no "affinity" for the steel. The plough-shares made by this process can be forged into any shape required by an ordinary blacksmith, or after it is entirely worn out he may draw it down into tools and cutlery. If the new process succeeds as well as it promises to do, we may soon see steel castings largely used instead of wrought iron or steel forgings for all difficult shapes. Mr. Nellis also has a patent on the mould used for his steel castings, which obviates the trouble experienced with iron moulds, of the melted steel adhering to them on all sides, and causing shrinkage cracks, and has all the advantage which iron moulds possess of durability and permanence of form. The moulds are made chiefly of iron, but with inserted sections of sand. These sections do not adhere to the casting, and shrinkage can take place without hindrance, avoiding cracks or internal strains.—*American Manufacturer.*

RAILWAY NOTES.

THE directors of the London, Brighton, and South Coast Railway Company have for some time past had under consideration the question of break power for their trains. Several kinds of patent breaks have been experimentally tried on the Brighton Railway, and particulars have also been obtained by the general manager and locomotive superintendent of that line of the various patent brakes at work both in this country and abroad, and, guided by general information and practical results of this kind, the directors have decided upon adopting the Westinghouse automatic brake for the passenger trains upon the Brighton system. Accordingly, an initiative order has been given by the Brighton Company for the fitting up of fifty engines and 500 carriages with the Westinghouse brake apparatus. In the course of a few weeks, therefore several of the London and Brighton express trains will be equipped with this efficient continuous break. In selecting the Westinghouse break the Brighton directors are of opinion that they will obtain for their passenger trains a continuous brake which will comply in all respects with the conditions laid down by the Board of Trade authorities. It should be mentioned also that the Brighton Company have for some time past had a large number of their engines fitted up with an efficient steam break designed by their locomotive superintendent, Mr. Stroudly. The Western Railway of France Company, with whom the Brighton Company have working arrangements for the through traffic between London and Paris by the Dieppe route, have likewise decided upon introducing the Westinghouse automatic brake in their trains between Dieppe and Paris, and other parts of their line.

IT was stated in the course of a recent debate in the Prussian Lower House that at the present time nearly half the railways in the kingdom are the property of the State, or under Government management. There are 10,625 miles of railway in Prussia, of which 5500 miles belong to private companies, while 2937 miles belong to the State, and 2188 are worked by Government. Three years ago the respective proportions were 4509 miles belonging to private companies, 2522 miles belonging to the State, and 1542 worked by it. Thus there is an increasing tendency upon the part of the State to acquire the private lines, and the reform of the traffic which the Government has decided upon with regard to its own lines, but which the private companies are unwilling to accept, is expected to lead to a struggle which will probably end to the disadvantage of the latter. The struggle is not confined within the frontiers of Prussia, for its policy with regard to the railways concerns the whole German system, as there is a great competition between the Prussian main lines worked by the State and the parallel lines in other parts of the empire. During the same debate the Minister of Commerce, questioned as to the policy of his Government, said that he was not in favor of the absolute system of State railways: "The Government merely wishes to acquire, by possession of some lines of its own, the power of exercising a regulating influence over the whole railway system. This is why we have sought to gain possession of the lines which had almost a monopoly of traffic, and we cannot see how such a step can have created any alarm among railway shareholders at large."

THE report of the Ministerial Department of Crown Lands and Public Works at the Cape has recently been published, showing, among other information, the progress made in railways during the past year. A total of 141¼ miles are now open for the public traffic in the colony, consisting of fifty eight miles of the main line from Capetown to Wellington, sixty-four miles of the Ceres-road and Worcester Railway, six miles of the Wynberg branch line and thirteen and a-quarter miles of loop line from D'Urban road to Moulders Vley. The total capital expenditure on the open railways of the Western system to December 31st, 1876 was £1,259,313. During the year 620513 passengers were carried (irrespective of season-ticket holders), against 581,349 in 1875, the average fare being 1s. 7d. against 1s. 4d. in 1875. A total of 97,206 tons of goods were carried, against 89 521 tons in 1875, the average charge per ton being 13s. 0½d. in 1875 against 12s. 9½d. in 1876. A total of 279,737 miles were run during the year, at a cost of 5s. 1d. per train mile, as compared with 5s. 7½d. in 1875, and 6s. 2½d. in 1874. No fatal accidents occured to any passengers. The report of the eastern district shows that at the end of 1876 a total of sixty-seven miles of railway were open severally between Port Elizabeth and Sand Flats, and between Zwaartkops Junction and Uitenharge. The working expenses of these lines averaged nearly 6s. 3½d. per train mile, but as yet, owing to the limited lengths open for traffic, the railway has hitherto been unable to compete with the ox-wagon. A line is also in process of construc-

tion between East London and King William's Town, a distance of ninety miles, at a cost up to the present time of £805,923. A total of from 1300 to 2500 men have been employed on this line, of which from 800 to 1850 were natives, 103 artisans, and seventy-two navvies who had been imported from Europe in 1876, making a total of 587 men of these classes engaged since the commencement of the work. A total length of fifty-six miles is now opened for passenger traffic in this district.—*Engineer.*

ENGINEERING STRUCTURES.

THE EAST RIVER BRIDGE.—At a meeting of the trustees on the 4th of March, Chief Engineer W. A. Roebling reported upon a method of passenger transit, showing that the original plan of the Bridge contemplated three sidewalks, two railroad tracks, and two single wagon tracks. The great exposure to the weather and the great length of the bridge, however, caused the Chief Engineer to decide that three sidewalks were unnecessary; two were accordingly abolished, and by widening the whole bridge five feet, two more wagon tracks were added, so that the bridge will have two double tracks, each eighteen feet and seven inches in width, for vehicles; two railroad tracks, each thirteen feet in width; and a central promenade for pedestrians, also thirteen feet in width.

The railroad trains will be attached to an endless wire rope, to be propelled by a stationary engine on the Brooklyn side. It was estimated by the late John A. Roebling that a speed of twenty miles an hour, which could be increased to thirty or even forty miles, would be perfectly safe. The cars will be fifty feet in length, and capable of seating 100 persons comfortably. The doors will be on the sides. Passengers will pay their fares at a toll house before entering the cars. The cars are to be built of iron and steel. No flooring is to be laid under the tracks, in order to prevent obstruction from snow, but there will be an iron grating to prevent persons from falling through. The stretching of the cables is being steadily prosecuted, and the great revolving wheels, which pay out the wires two at a time, are the daily objects of attraction to the numerous passengers by the ferry boats.

IRON BUILDING.—An iron structure has just been erected for the Youngstown Rolling Mill Company, at Youngstown, O. The company determined to replace their rolling mill with a building of iron, and plans and bids were tendered by several prominent firms. The plans and specifications furnished by Mr. Alexander E. Brown, C.E., of Cleveland, were approved, and a contract made with him for the structure throughout and complete. The finishing work was done, and the building turned over to the owners on the last day of December, and was accepted as in every respect satisfactory. Practical mill men, pronounce it one of the best, if not the very best building of the kind in the Western country, and give much credit to the young contractor for the excellence of the design and workmanship.

As most of the machinery is driven by belts, a very stiff frame is required to carry the lines of shafting and heavy pulleys. The strain upon every post, beam, rod and rafter in the complicated map of framework was carefully calculated, and proportioned with a strength of four times the actual strain, to be borne by it—in other words, with a factor of safety of four. The building is 140 feet long by 160 feet wide, the roof bridge being about 47 feet above the stone foundations, and consists of a central building 100 feet wide with a shed on each side thirty feet wide, the whole supported upon forty iron posts; those of the main or central part twenty-seven feet high. These columns are made of a combination of "T" rails, patented by Mr. Brown, and while they are equal if not superior in strength, are much less costly than those made with the column irons generally used. The entire roof and sides, to within eight feet of the ground, are covered with heavy corrugated iron, riveted to the frame, and thoroughly painted.

A ventilator runs the entire length of the roof at the ridge, and light is admitted through two skylights eight by seventeen feet in the main roof, and through a row of windows under the eaves of the main or central building, and above the roof of the sheds, and also under the eaves of the sheds and at the ends of the building. Not a foot of timber or wood was used in the construction of this building, and its cost will soon be reimbursed to its owners by the saving of all cost for insurance.—*Cleveland Journal.*

THE ST. GOTHARD TUNNEL.—Up to the first of the last month, 321,108 feet of the St. Gothard Tunnel had been perforated, 16,800 feet at the north (Goeschenen) end, and 15,308 feet at the south (Airolo) end. At present the work is rendered very difficult. On the north side for the last three months the borings have passed through serpentine, and on the south side through broken rock, which has required the greatest possible precaution to deal with. The mean progress has not lately exceeded thirteen feet per day.

ORDNANCE AND NAVAL.

TWO NEW IRONCLADS.—The British Government has added two powerful war vessels to the navy of Great Britain by the acquirement of the ironclad *Payki Sherref*, lately in Millwall Dock, and her sister ship, at present unnamed, and on the stocks at the adjacent building yard of Messrs. Samuda, nearly opposite Greenwich. The *Payki Sherref*, which the Lords of the Admiralty recognise at present only by the title of "B 71," is finished, and furnished ready for sea, and the other ship is proposed to be like her in every respect. Technically speaking, the *Payki Sherref* is an iron armor-cased corvette, with a raised fighting battery deck amidships. The battery deck rises from below the water line to a height of about 18 feet, and mounts four 25-ton

guns 12-inch muzzle-loaders, which are already on board, having been provided by Sir Wm. Armstrong when the ship was built for the Turkish Government, more than a year since, and detained as contraband of war. Two of the guns fight on the port and two on the starboard side, each pair being provided with gun-metal racers, giving them such scope for traversing that they can fire direct fore and aft, or combinate upon one spot at 90 yards range. There is ample room to work the guns, the battery deck being an octagon of about 60 feet, while the guns, which are somewhat short in the chase, are 16 feet in length. They are rifled with eight grooves, and on an increasing twist. The projectiles as well as the guns are already on board, consisting of 650 12-inch shot and shell for the big guns, and some 200 for the 9-pounder guns, which will probably be mounted in the bows and astern. The larger projectiles comprise 240 chilled shells, on the Palliser principle, 100 chilled shot, 240 common shell, 70 shrapnel, and 170 segment shells. The armor plating consists of a belt of 12-inch iron at the water line, diminishing above and below to 8 inches, the thickness of iron protecting the battery varying from 9½ to 10½ inches. The main deck, which will be nearly level with the water, is composed of 3 inch plates of armor, encased in oak. The designer of the ship was Hemit Pacha, of the Turkish navy, and for her length she is remarkably spacious. She measures between perpendiculars 245 feet, and has a breadth of nearly 60 feet even at a few feet from the stem and stern. Her burden in tons is 3075, builder's measurement, and her draught of water 19 feet forward and 19 feet 6 inches aft. Her displacement at the load-line is 4777 feet, and the area of her midship section 895.68 square feet. She is propelled by a pair of engines constructed by Messrs. Maudslay & Field, having a nominal horse-power of 600 and 3900 indicated. The guaranteed speed is twelve knots an hour. There is a steam steering apparatus and wheels to be worked by hand, both on the battery deck and under cover of the lower deck, and provision is made to cook for 350 men, while thirteen tanks are on board to contain 8000 gallons of water. The *Payki Sherref* is to undergo some slight alterations, which will be executed at Sheerness Dockyard. The other ship, now building, can be completed in a few months, and will be brought forward with all speed. Both ships have been surveyed and approved of by the Lords of the Admiralty.

THE JAPANESE IRONCLADS.—The three warships building in England for the Imperial Japanese Government from the designs of Mr. E. J. Reed have now all been tried under steam, and are expected to sail for Japan in the course of the next few weeks. The official speed trials have given very satisfactory results. The Foo-so, an iron vessel, 220 feet long and 48 feet extreme breadth, plated with 9 inch of armor, was tried upon the measured mile at the Maplin Sands on the 3rd inst. She has eight cylindrical boilers each 11 feet 3 inches in diameter, working at 60 pounds pressure, and two pairs of Messrs. Penn's horizontal compound trunk engines driving twin screws, 15 feet 6 inches in diameter, with a pitch of 16 feet. The cylinders are 58 inches and 88 inches in diameter with 30 inch trunks, and the stroke is 30 inches. Her draught was 17 feet 1 inch forward and 18 feet 1 inch aft, the immersed area of midship section was 788 square feet and the displacement 3639 tons. The vessel was under way 8¼ hours in all, and steamed at full speed without stopping for about three hours. Six runs were made upon the mile, which resulted in a mean speed of 13.16 knots per hour with an indicated horse power of 3824. The estimated speed was 13 knots. The number of revolutions made was from 93 to 94. A steady pressure of 59 pounds per square inch was kept in the boilers during the trial, and in both condensers the vacuum was 27 inches.

The Foo-so showed excellent maneuvering powers, answering quickly to the action of the helm, turning in a very small circle. The engines worked very smoothly and satisfactorily. The builders of the ship are Messrs. Samuda Brothers of Poplar.

The Kon-go, a composite corvette of 231 feet in length, 40 feet 9 inches extreme breadth, and 17 feet 6 inches draught of water, built and engined by Earle's Shipbuilding and Engineering Company (Limited), of Hull, made her official speed trials off the mouth of the Humber on the 7th of December last. The engines are horizontal compound with return connecting rods. The cylinders are 60 inches and 99 inches diameter, and the stroke 33 inches. They are constructed to work with a boiler pressure of 60 pounds and to indicate 2500 horse power. The screw propeller is 16 feet in diameter with a pitch of 17 feet 6 inches. In the notice we gave of these ships on the 16th of November we said, that the speed expected of the Kon-go and her sister ship the Hi-yei, to be noticed presently, was 13½ knots, but that judging from the beauty of their lines and the magnitude of the engine power it was not unlikely that that estimate would be considerably exceeded.

Six runs were made by the Kon-go over a measured mile at Withernsea, which is on the Yorkshire coast a few miles north of Spurn Head, with the following results. The steam pressure was kept steadily at 60 pounds and 61 pounds per square inch in the boilers; the vacuum was 25½ inches, and the revolutions increased during the trial from 82 at the commencement to 87 at the close. The power indicated was 2450. The mean of the six runs was 13¾ knots, but each pair of runs was so much better than those which preceded it, that if the day had been longer so as to have enabled one or two more pairs of runs to be made, the means of the last six runs would, in the opinion of Mr. Reed and the engineers on board, have reached 16 knots.

The remaining vessel, the Hi-yei, a sister ship to the Kon-go, built by the Milford Haven Shipbuilding and Engineering Company (Limited) at their works at Pembroke Dock, South Wales, and engined by the engineers of the Kon-go, made her official speed trials on the

26th ult. off Cardiff. The distance upon which she was run was bounded by a buoy and a lightship, and measurements taken upon a chart showed that the mean of four runs gave a speed of about 14½ knots per hour. A patent log that was left out during the whole time the vessel was running, and which would show less than the true speed owing to the loss that would take place in turning at the end of each run, indicated a speed of 13.915 knots per hour. This would show that the Hi-yei considerably exceeded 14 knots, and that the class of vessels she represents are able to do a good 14 knots per hour over the measured mile. The trial of the Kon-go points to the same result, as there was every appearance of reaching 14 knots with her if there had been sufficient day-light to have kept running her. The performance of the engines was considered highly satisfactory and an indicated horse power of 2490 was obtained.

The trials of these vessels have been made under the personal directions of Mr. E. J. Reed, and in the presence of His Excellency the Japanese Minister and suite.

BOOK NOTICES

THE ANEROID, ITS CONSTRUCTION AND USE. Science Series No. 35. New York: D. Van Nostrand. Price 50 cts.

This little manual is designed for those who desire to apply the Aneroid to its legitimate use of measuring altitudes.

The late improvements in the manufacture of this instrument have rendered it as reliable in careful hands as the mercurial barometer, while it is infinitely more portable.

The book is compiled from the latest reliable sources, and affords short formulas for such approximate results as will satisfy the tourist as well as the most complete formulas and tables for the use of engineers.

For reconnoissance surveys the Aneroid safely replaces the level, and is rapidly coming into use for such purposes.

The principal tables in the book are those of Prof. Airy derived from his formula, and a table of five place logarithms for the application of La Place's formula.

The practical part of the book is preceded by a treatise of atmospheric pressure and the use of the Barometer in weather observations.

A portion of the book has appeared in this Magazine.

BUILDING CONSTRUCTION. By R. SCOTT BURN. London: William Collins, Sons & Co. For sale by D. Van Nostrand. Price $3.00.

This is a new book by a well known author on kindred subjects, and is designed as a convenient manual for the designer of structures of different kinds, and embracing the use of timber, lead and iron.

The four parts treat respectively of Carpentry, Joinery, Iron, Lead and Zinc Work, and Miscellaneous Roof Coverings, Staircases, Strains.

The text book is illustrated by 480 cuts interspersed, and is accompanied by an Atlas of 60 plates.

WEATHER WARNINGS AND WATCHERS. By "THE CLERK" HIMSELF. London: Houlston & Sons. For sale by D. Van Nostrand. Price 50 cts.

The title of this book is pretentious and misleading. It is but little more than a thin treatise on instruments used in Meteorology, well illustrated.

THE YEAR-BOOK OF FACTS IN SCIENCE AND ART. By JAMES MASON. London: Ward, Lock & Co. For sale by D. Van Nostrand. Price $1.25.

This contains apparently less matter than usual, but presents the same variety as ever. Entomology has its full share of attention, the only illustration being a magnified Colorado beetle.

GEOLOGICAL SURVEY OF NEW JERSEY. By GEO. H. COOK, State Geologist. Trenton: Noar, Day & Noar, Printers.

The present report relates to the clay deposits of New Jersey, and their uses for fire brick, pottery, etc. Like its predecessors it is a valuable addition to the literature of economic geology. The analyses of the various clays are given and their locations fully described both by topographical charts and by vertical sections.

The maps are exceedingly good. The report covers 380 octavo pages.

MISCELLANEOUS PAPERS ON PHYSICAL SCIENCE. By HUMPHREY LLOYD, D. C. L. London: Longmans, Green & Co. For sale by D. Van Nostrand. Price $6.40.

The author of these papers, now Provost of Trinity College, Dublin, was formerly Professor of Natural Philosophy in that university.

The papers, twenty-three in number, embrace subjects relating to Optics, Meteorology, and Terrestial Magnetism, especially the latter.

It is a well printed, royal octavo of 510 pages, with a few illustrations, including a finely engraved magnetic chart of Ireland.

THERMODYNAMICS. By P. G. TAIT, M. A. Second Edition. Edinburgh: David Douglas. For sale by D. Van Nostrand. Price $2.50.

This new edition comes in an excellent typographical dress, which is eminently fitting to a treatise every page of which threatens the reader with a headache unless he is fresh in his mathematics.

Prof. Tait is an acknowledged master of the higher analyses and especially in the line of physical research.

REPORT ON THE IRON MANUFACTURE OF UNITED STATES OF AMERICA. By I. LOWTHIAN BELL, Esq., F. R. S. London: Eyre & Spottiswoode. For sale by D. Van Nostrand. Price 60 cts.

The substance of this pamphlet has already appeared in our pages. It presents in the most satisfactory manner a comparison of the methods of manufacture of iron and steel in this country with that of Great Britain, and will always be a valuable record because prepared from personal observation by the person best qualified to do it.

A MANUAL OF ENGINEERING SPECIFICATIONS AND CONTRACTS. By Prof. LEWIS M. HAUPT. Philadelphia: J. M. Stoddart & Co. For sale by D. Van Nostrand. Price $3.00.

This is an instructive manual of an uncommon kind, but of the highest importance to the young engineer. It covers that branch of engineering education which can be satisfactorily learned from a book without other aid. Even experienced engineers cannot afford to trust to memory alone in drawing specifications, and will find a carefully prepared book of valuable service.

The topics treated by chapters are as follows: Chapter 1, Drawings; Chap. 2, Estimates and Measurements; Chap. 3, Specifications; Chap. 4, Advertisements; Chap. 5, Bids or Proposals; Chap. 6, Contracts.

Numerous illustrative examples are given, the whole covering something over 300 octavo pages.

THE ROYAL NAVY LIST, containing Dates of all Commissions, &c., and a Statement of the War and Meritorious Services, Medals, Decorations, Honors, &c., of the Officers of the Royal Navy and Royal Marines on the Active and Retired Lists. By C. E. WARREN, R. N., and Lieut.-Colonel F. LEAN, R. M. L. I. January, 1878. London: Witherby & Co. For sale by D. Van Nostrand. Price $3.00

This is a new quarterly. The following is from the *Army and Navy:*

"The Naval Service is to be congratulated on the appearance of this much-required work, and the Editors deserve every support for the enterprize they have shown in undertaking the great labor and cost of publication. The scope of the List will be recognized when we state that it contains all that is to be found in the quarterly official 'Navy List,' together with the following important additions. The dates of all commissions held by an officer are given, so that the rapidity, or otherwise, of his progress can be seen at a glance, while by foot-notes on each page reference is made to any special causes of promotion. The War and Meritorious Services of Officers of all grades are given in another part of the book, and this portion of the List will be made a most valuable record if officers themselves will give the Editors the assistance they ask and forward particulars of their services. There are also recorded the deeds by which the Victoria Cross, Albert Medal, the Awards of the Humane Society, and other institutions have been won. The type is excellent, and the system upon which the names have been arranged and references are given in the different lists make the work of tracing an officer's career quite easy, instead of being a labor. Next quarter the List will be enlarged, owing to additional information being received from a variety of sources, and the price will have to be raised to meet the increased cost of production; but we feel sure that the Service will appreciate the appearance of this Naval 'Hart,' and will not allow it to suffer from any want of support."

THE PATTERN MAKER'S ASSISTANT, embracing Lathe Work, Branch Work, Core Work, Sweep Work and Practical Gear Construction. By JOSHUA L. ROSE, M. E. New York: D. Van Nostrand. Price $2.50

The author of this practical treatise is well-known on both sides of the Atlantic, through his contributions to technical journals upon tools and their use.

The collected papers form a work entitled "The Complete Practical Mechanic," a work of the most thoroughly practical character.

The present work is illustrated with 244 cuts, and besides a large collection of valuable tables presents the following topics:

Contents: Chapter I, General Remarks; Selection of Wood; Warping of Wood; Drying of Wood; Plane-irons; Grinding Plane irons; Descriptions of Planes; Chisels; Gouges; Compasses; Squares; Gages; Trammels; Winding-strips; Screw-driver; Mallet; Calipers. Chap. II, Lathe; Lathe Hand-rest; Lathe Head; Lathe Tail-stock; Lathe Fork; Lathe Chucks; Gouge; Skew-chisel; Turning Tools. Chap. III, Molding Flask; How a Pattern is Molded; Snap Flask. Chap. IV, Description of Cores; Core boxes; Examples of Cores; Swept Cores for Pipes, etc. Chap. V, Solid Gland Pattern; Molding Solid Gland Pattern; Gland-pattern without Core-print; Gland Pattern made in Halves; Bearing or Brass Pattern; Rapping Patterns; Example in Turning; Sand-papering; Pattern Pegs; Pattern Dog or Staple; Varnishing; Hexagon Gage; Scriber. Chap. VI, Example in T-joints, or Branch Pipes; Example in Angular Branch Pipes; Core Box for Branch Pipes. Chap. VII, Double-flanged Pulley; Molding Double-flange Pulley; Building up Patterns; Shooting-board; Jointing Spokes. Chap. VIII, Pipe Bend; Core-box for Pipe Bend; Swept Core for Pipe Bend; Staving or Lagging; Lagging Steam Pipes. Chap. IX, Globe Valve; Chucking Globe Valve; Core-boxes for Globe Valve. Chap. X, Bench-aid; Bench-stop; Bench-hook; Mortise and Tenon; Half-lap Joint; Dovetail Joint; Mitre Box; Pillow Block. Chap. XI, Square Column; Block for Square Column; Ornaments for Square Column; Cores for Square Columns; Patterns for Round Columns. Chap. XII, Thin Work; Window Sill; Blocks for Window Sill. Chap. XIII, Sweep and Loam Work; Sweeping up a Boiler; Sweep Spindle; Sweeping up an Engine Cylinder. Chap. XIV, Gear-wheels; Construction of Pinion; Construction of Wheel-teeth; Gage for Wheel-teeth; Bevel Wheels; Building-up Bevel-wheels; Worm Patterns; Turning Screw of Worm Pattern; Cutting Worm by Hand; Wheel Scale. Chap. XV, Patterns for Pulleys; Section Patterns. Chap. XVI, Cogging; Wood used for Cogging; Templates for Cog-Teeth; Sawing out Cogged Teeth; Boring Cogged Teeth; Chap. XVII, Machine Tools for Pattern Making; Face Lathe; Jig Saw; Band Saw; Circular Saw; Planing Machine; Glue Pot. Chap. XVIII, Shrinkage of Solid Cylinders; Shrinkage of Globes; Shrinkage of Disks; Shrinkage of Round Square Bars; Shrinkage of Rectangular Tubes; Shrinkage of U-shaped Castings; Shrinkage of Wedge-shaped Castings; Shrinkage of Ribs on Plates; General Laws of Shrinkage; Table of Shrinkage; Calculating Thickness of Thin Pipes; Calculating Thickness of Cylin-

ders for Hydraulic Presses; Calculating Rims of Fly-wheels.

CORRECTION. — The reviewer of Du Bois' "Graphical Statics" writes that he was in error in stating (on p. 191) that "the kernel of Fig. 37, plate II. is wrong side up." But it should be added that Du Bois makes a mistake in connection with the discussion of this figure, for the note at the bottom of page 77 should be corrected by multiplying both members of the first equation by $\sin. \Phi$.

MISCELLANEOUS.

MESSRS. SMITH, FASSETT & Co., of Tonawanda, N. Y., report having shipped the past season over 70,000,000 feet of lumber, besides a proportionate quantity of shingles, lath, etc., an increase of almost 100 per cent. over their business of last year. They deal exclusively in Michigan pine, which is shipped from their docks to customers in New York, Pennsylvania, Maryland, and sections still further east. Their facilities for handling lumber are such as to enable them to manipulate their stock easily and economically. They have a dock frontage of 2,700 feet and storage room for an ample supply of everything which it is necessary for them to sell. The rapid growth of the business represented by this firm is no doubt due in a great measure to the practical knowledge of the trade possessed by each of its members.

IT is very well known that if the air in sewers could be kept in continual motion in one direction, so that no stagnation could take place, the danger attending the development of sewer gases would be avoided. To this end vertical shafts have been proposed and tried without success, for causing the upward current of the sewer gas or air. Similar shafts are now proposed by Mr. R. Parker, surveyor to the Board of Works for the Poplar district, but in place of using them as uptakes he provides their upper ends with a cowl, the opening of which is always presented to the wind which enters the sewers and keeps up a current that constantly changes the gaseous contents of the sewer by driving them out at every opening. Mr. Parker proposes to use "a number of cast iron shafts erected about 12 feet high and 10 inches diameter, in convenient and open places, and also pipes of various sizes according to circumstances, from the sewers and existing drains at the rear of houses, to the house top as high as the chimney stack, and these pipes or ventilating shafts should be surmounted by a cowl, guided by a vane attached to it, so that its opening or aperture shall always be facing the wind. The air or wind impinging upon it will force down the air within it, and pass into the sewer and travel along it, entering all drains and ramifications to find an outlet so that it may escape. The air within the sewer requires very little force to cause it to move forward, as it has in itself a tendency to move upwards." He has made some experiments which are described in a recent report to the Poplar Board, "to see if the force of the wind and air could be conducted into the sewers, in this way to force out the gases and keep up a constant current of fresh air; it has been found that there was always a downward current in the ventilating shaft, and an upward rush of pure air in all the gulleys and drains in its immediate neighborhood." A shaft was constructed from a drain to the roof of a house in Bow, the distance from the cowl to the sewer being 13 feet. The average results of the first seven experiments gave:—Temperature outside sewer, 43.28 deg.; temperature inside sewer, 48.86 deg.; velocity of wind outside sewer, 4.61 miles per hour; velocity of wind at junction of 9 inches drain in sewer, 1.81 miles per hour. Cubic feet of air forced into sewer per hour, 4210.

THE FALL OF A MOUNTAIN IN SAVOY.—An interesting account of the recent falling of a mountain in Tarentaise, Savoy, causing disaster to two flourishing villages, has been communicated to the *Courrier des Alpes*, by M. Bérard. The phenomenon has been incorrectly reported as instantaneous and the destructive effect complete, whereas the case is that of a mountain which for twenty days, without cessation, has been dismembering itself and literally falling, night and day, into the valley below, filling it with piled-up blocks of stone, extinguishing all sounds by its incessant thunder, and covering the distant horizon with a thick cloud of yellowish dust. The entire mass comprised in the slope forms a mutilated cone 200 meters broad at the top and 600 at the base (the slope being about 50 degrees); this is composed of hard schist lying close together, but no longer united; and it is united to the body of the mountain only by a vertical mass of 40 or 50 meters thick, which is already fissured and shaken. Periods of repose occur, lasting only a few seconds; or a minute at most; then the movement recommences and continues about 500 hours. Blocks of 40 cubic meters become displaced with no apparent cause, traverse the 1,800 meters of descent in thirty seconds, leaping 400 or 500 meters at a time, and finally get dashed to pieces in the bed of the torrent, or launch their shattered fragments into the opposite forest, mowing down gigantic pines as if they were so may thistles. One such block was seen to strike a fine fir-tree before reaching the bridge between the villages; the tree was not simply broken or overthrown, but was crushed to dust (*volatilisé*); trunk and branches disappeared in the air like a burning match. Rocks are hurled together and broken into fragments that are thrown across the valley like sparrows in a whirlwind; then follow showers of smaller fragments, and one hears the whistling sound of thousands of pebbles as they pass. M. Bérard reached the edge of the rock (2,460 meters high) on one of the sides of the falling cone, and ventured along it obtaining a good view of the "terifying" spectacle. He reaffirms his conviction that the phenomenon is inexplicable by any of the usual reasons that account for Alpine disturbances, such as penetration of water or melting of snows, or inferior strata in motion; nor does the declivity of the slope explain it.—*Nature*.